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FINAL REPORT FOR COOPERATIVE AGREEMENT #
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SYSTEMS FOR ENVIRONMENTAL MANAGEMENT
Co-op Contact: Larry S. Bradshaw
FS Contact: Stephen Arno

Estimating Emissions From Wilderness Fires and Resultant Smoke in the Bitterroot and Missoula Valleys

An aspect in evaluating the effectiveness
of a fire management plan established in 1972
to return fire to its natural role
in the Selway-Bitterroot Wilderness area.

Final Report

Submitted by:

Larry S. Bradshaw

SYSTEMS FOR ENVIRONMENTAL MANAGEMENT

P.O. BOX 8868
MISSOULA, MONTANA 59807
PHONE: (406) 549-7478

SYSTEMS FOR ENVIRONMENTAL MANAGEMENT

A Natural Resources Research Group

Systems for Environmental Management (SEM) is a non-profit research and educational corporation based in Missoula, Montana, a regional center for natural resources agencies. Founded in 1977, SEM works cooperatively and under contract with the U.S. Forest Service, National Park Service, Bureau of Land Management, and Bureau of Indian Affairs, as well as state and academic institutions, private individuals and organizations.

SEM's diverse professional staff offers a wide range of research capabilities within the natural resources management field. The full-time staff includes specialists in fire behavior, fire history, recreation management, geography, plant ecology, forestry, meteorology, data analysis, and computer science. SEM also maintains a pool of professional affiliates that can be utilized for projects requiring additional expertise. Areas of recent research emphasis include wilderness recreation management, fire history and ecology, fire planning, and development of computerized resource management tools.

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Systems for Environmental Management
October 1992

Preface

This report is submitted in fulfillment of Section II(A) of cooperative agreement No. INT-88330-COA (amended) between the Intermountain Research Station and Systems for Environmental Management (SEM).

This research was supported in part by funds provided by the Intermountain Research Station, Forest Service, U.S. Department of Agriculture and constitutes the fourth objective in a study evaluating the effectiveness of the Selway-Bitterroot Fire Management plan in its efforts to allow fire to return to a natural role in the Selway-Bitterroot Wilderness (SBW) area.

In the first objective Barrett (1990) characterized primeval fire regimes in the SBW area in Northwestern Montana and Northeastern Idaho. He identified eight basic forest cover types in the SBW with associated fire regime types. Fire regime classifications were based on Barrett's (1988 unpub. rep. 'Fire Regimes Classification for Coniferous Forests of the Northwestern United States', on file, Intermountain Research Station) severity/spread pattern key.

The fire regime key combines a severity class with a pattern class (i.e. Lethal/Mixed, Non-lethal/uniform, etc..) to describe the general fire regime of an area. The severity class generally has an implied frequency of fire intervals (lethal fire regimes burn less frequently than non-lethal regimes). The distribution of the fire regimes were summarized across elevation, topographic, and geographic classification schemes.

The second objective, under the direction of the Fire Effects Research Work Unit at the Intermountain Fire Sciences Laboratory, characterized modern (post-1972) fire occurrence (unsuppressed and suppressed) in the SBW, and stratified the modern burns by the primeval fire regimes.

The third objective, also under the direction of the Fire Effects RWU, compared the frequency and severity of fires by fire regime type for the primeval and modern eras.

The work described here utilizes the results from the first three objectives and attempts to characterize smoke production and document impacts (periodicity, duration, concentration/visibility) from SBW fires during a period of total fire control (1960-1971) and a period of prescribed-natural fire management (1972-1990) in the SBW. It further attempts to establish a basis for estimating the production and impacts of smoke during a primeval period. The impact of smoke on the Bitterroot and Missoula valleys is discussed over matrix of fire management alternatives.

Acknowledgement

Arnold Finklin, retired, did all of the library research for this study. He spent numerous days in Bozeman at the Montana State Climatologist Office, the University of Montana Library, the Missoula Weather Service, and the Hamilton Public Library. He also used his extensive personal library and knowledge of the climate of the Selway-Bitterroot to classify upper air charts in an unsuccessful attempt to correlate upper air map types with smoke episodes.

Introduction

Though occasional smoke from forest fires is a traditional aspect of many summers in the Northern Rocky mountains, events of extremely dense smoke have always been noteworthy. In a session on the Ecological and Historical Role of Fire, Jack Losensky (Ecologist, Region 1) documented (source unknown) a story from July 28, 1889 in Philipsburg, Montana:

> "For the past two or three days the sky around Philipsburg has been filled with smoke but little attention was paid at first, as such has often been the case before, only to a much smaller extent today it has absolutely become uncomfortable so dense it has become... the whole of Flint Creek valley is densely covered with smoke and the people on the ranches are getting alarmed... the smoke is getting so thick to affect the eyes. In Drummond houses had to be lighted up at 5:30 so dark it had become... It is no ordinary smoke, such as we have pretty near every year, but it is a smoke you can taste, smell, feel, and almost handle..."

Similar stories can be told of other summers as huge forest fires periodically burned in western states. Ward and Hardy (1991) chronicle several of these and quote from Plummer (1912) that

> "these phenomena, observed from time immemorial, have been known by various names--in this country as dark days, dry fogs, Indian summers and colored rains."

The half-million hectare (1.2 million ac) Selway-Bitterroot wilderness is located in northeastern Idaho and an adjacent portion of western Montana and lies within portions of the Bitterroot, Clearwater, Lolo, and Nez Perce National Forests of the Forest Services' Northern Region. In 1972, a small portion of the Wilderness was released from almost 40 years of the "Ten a.m. Policy" under which all fires were attacked with adequate forces to render them under control by 10 a.m. the following day. In 1976, after a five year evaluation of the wilderness natural fire management, the entire Wilderness came under a new Fire Management Plan. The Final Environmental Statement on Fire Management in the Selway-Bitterroot Wilderness (USDA Forest Service, 1976) contains an excellent essay on potential effects of smoke on the Selway-Bitterroot and nearby airsheds. It concludes that expanding the wilderness natural fire management (from the original Whitecap and Bear Creek drainages to the entire SBW) was "not expected to effect an airshed particulate loading in excess of its historic loading from wildfires in pre-control days."

It notes a study by Mehringer (1975) of airborne charcoal deposition in Lost Trail Bog. This deposition, much of which is assumed to come from forest fires, has been occurring for 11,000 years with the greatest deposition rates in the last 2,000 years. The environmental statement also cites work by Leiberg (1900) and Arno (1976) that document fire as a continuing feature of most of the Bitterroot Forest since at least the 1600's.

The Final Environmental Statement identified a range of impacts of smoke on social and economic concerns. We will try to quantify this study in terms of the broad categories in this matrix. A note of interest-- of some 82 letters that were sent in during the public comment period, only eight mentioned the effects of smoke; two felt smoke would effect them adversely and five felt smoke would probably be of little or no concern. (A note of personal interest-- by far most respondents were in favor of burning to increase elk herds and many had very specific drainages and hillsides they wanted the Forest

Service to burn for them as soon as possible...)

Fire Occurrence and Emission Estimates Under Prescribed Natural Fire Management

The number of fires and area burned for SBW fires from 1972 through 1990 for prescribed natural fires, wildfires, and total fires are shown in figures 1a through 1c. (Data from USDA Forest Service, Region 1, Aviation & Fire Management, Appendix A). In total 1,101 fires burned 60,366 ha (149,166 ac). This 19 year period had a total of 787 wildfires burning 35,734 ha (88,299 ac) and 314 prescribed natural fires burning a total of 24,632 ha (60,867 ac). Those classified as wild fires (70 percent) burned about 60 percent of the total area burned, while the 30 percent classified as prescribed fires burned about 40 percent of 60,000 hectares.

These figures include 1988 in which wildfires burned over 24,000 ha (about forty percent of the total area burned in the SBW during the 19 year period). If the fires of 1988 were omitted, the ratio of wildfire to prescribed fire occurrence is the same, but wildfire accounts for just 30 percent of the area burned while prescribed natural fires account for almost 70 percent of the burned area.

The Fire Effects RWU did all the emissions estimate work. They compiled a master list of 137 SBW Class C (4 ha, 10 ac) and larger fires from 1977 to 1990 (Appendix B) using fire occurrence records from the National Fire Occurrence Data Library (Yancik and Rossopoulous, 1976). These 137 fires represent about 12 percent of the total fires in the 14 year period which includes the last two years of a five year period of low fire activity (1974-78), a five-year period of variable fire activity (1979-1983), and a seven-year period of relatively high fire activity (1984-1990). There were no large fires in the wilderness in 1977, 1978, or 1980, and only one in 1984.

Each fire was categorized as to its management status (prescribed-natural, wildfire-suppressed, wildfire-contain, wildfire-confine). The evolution of each fire was investigated through fire occurrence records, interviews with Fire Management Officers and other sources as available. Area burned and burn intensity (lethal crown fire, lethal underburn, non-lethal underburn, and unburned) was estimated for 10-day periods through the duration of the fire. Estimates were made for available fuel and fuel consumption (Brown 1991, unpublished report) for burned areas in each fire regime. The burned areas and intensities were combined with published emission factors (Ward and Hardy 1991) using low, average, and high combustion efficiencies to estimate emissions for each fire. Estimated emissions were total particulate matter (PM), particulates 2.5 microns and less (PM2.5), carbon monoxide (CO), and methane (CH4). Particulate 10 microns and less (PM10) were estimated from the relationship:

$$PM10 = PM2.5 + 0.17*(PM - PM2.5)$$

Appendix C contains the estimated emissions by forest (Bitterroot, Clearwater, Nez Perce) and 10-day burning period for the three levels of combustion efficiency. Table 1 consolidates the emission estimates for the forests and presents the estimated emissions based on average combustion efficiency in thousands of pounds and megagrams (Mg = 10^6 g).

Table 1. Estimated Total Wilderness Emissions Using Average Combustion Efficiency Coefficients, 1977-1990

		*** Emissions in Thousands of Pounds ***					****** Emissions in Mg (10**6) Grams ******				
Year	Period	PM Tot	PM10	PM2.5	CO	CH4	PM Tot	PM10	PM2.5	CO	CH4
1979	Jul 01-10	62	44	40	470	22	28	20	18	213	10
	Jul 11-20	250	179	164	1897	91	113	81	74	860	41
	Jul 21-31	816	579	531	6193	297	370	263	241	2809	135
	Aug 01-10	5958	4229	3875	45360	2174	2703	1918	1758	20575	986
	Aug 11-20	3198	2267	2076	24203	1162	1451	1028	942	10978	527
	Aug 21-31	132	94	86	1021	49	60	43	39	463	22
	Sep 01-10	493	349	320	3756	180	224	158	145	1704	82
	Sep 11-20	154	110	101	1187	57	70	50	46	538	26
	Sep 21-30	1214	863	791	9264	444	551	391	359	4202	201
	Oct 11-20	45	32	29	347	17	20	14	13	157	8
Total	10 Prds	12322	8746	8013	93698	4493	5589	3967	3635	42501	2038
1981	Jul 21-31	71	51	47	546	27	32	23	21	248	12
	Aug 01-10	211	150	138	1621	78	96	68	63	735	35
	Aug 11-20	328	233	213	2521	121	149	105	97	1144	55
	Aug 21-31	3945	2798	2563	29837	1435	1789	1269	1163	13534	651
	Sep 01-10	577	411	377	4419	211	262	186	171	2004	96
	Sep 11-20	1200	848	776	8997	432	544	385	352	4081	196
Total	6 Prds	6332	4491	4114	47941	2304	2872	2037	1866	21746	1045
1982	Jul 21-31	8	6	5	57	2	4	2	2	26	1
	Aug 21-31	201	143	131	1524	74	91	65	59	691	34
	Sep 21-30	13	8	7	95	5	6	4	3	43	2
Total	3 Prds	222	156	143	1676	81	101	71	65	760	37
1983	Aug 21-31	139	99	91	1072	51	63	45	41	486	23
Total	1 Prd	139	99	91	1072	51	63	45	41	486	23
1984	Aug 01-10	17	13	12	134	6	8	6	5	61	3
	Aug 11-20	106	75	69	805	40	48	34	31	365	18
	Aug 21-31	585	416	381	4463	212	265	189	173	2024	96
	Sep 01-10	99	69	63	748	35	45	31	29	339	16
Total	4 Prds	807	573	525	6150	293	366	260	238	2790	133
1985	Jul 01-10	8	4	3	55	2	4	2	1	25	1
	Jul 11-20	551	392	359	4196	202	250	178	163	1903	92
	Jul 21-31	3499	2484	2276	26646	1276	1587	1127	1032	12087	579
	Aug 01-10	7	5	4	47	2	3	2	2	21	1
	Aug 11-20	149	107	98	1163	55	68	48	44	528	25
	Sep 01-10	140	100	92	1069	51	64	45	42	485	23
Total	6 Prds	4354	3091	2832	33176	1588	1975	1402	1285	15049	720
1986	Jul 01-10	19	14	13	151	7	9	6	6	68	3
	Jul 21-31	48	35	32	372	17	22	16	15	169	8
	Aug 01-10	1661	1177	1078	12569	603	753	534	489	5701	274
	Aug 11-20	2621	1867	1712	20054	960	1189	847	777	9096	435
	Aug 21-31	2185	1553	1424	16825	806	991	705	646	7632	366
	Sep 01-10	149	107	98	1156	55	68	48	44	524	25
Total	6 Prds	6683	4752	4357	51127	2448	3031	2156	1976	23191	1110

Table 1 (con't). Estimated Total Wilderness Emissions Using Average Combustion Efficiency Coefficients, 1977-1990

Year	Period	*** Emissions in Thousands of Pounds *** PM Tot	PM10	PM2.5	CO	CH4	****** Emissions in Mg (10**6) Grams ****** PM Total	PM10	PM2.5	CO	CH4
1987	Jul 11-20	78	55	50	597	29	35	25	23	271	13
	Aug 01-10	646	458	420	4929	237	293	208	191	2236	108
	Aug 11-20	60	43	39	457	22	27	19	18	207	10
	Aug 21-31	89	63	58	687	33	40	29	26	312	15
	Sep 01-10	62	44	40	475	22	28	20	18	215	10
	Sep 11-20	3557	2524	2313	27087	1298	1613	1145	1049	12287	589
	Sep 21-30	1977	1403	1286	15078	723	897	637	583	6839	328
	Oct 01-10	1717	1218	1116	13019	625	779	553	506	5905	284
	Oct 11-21	694	492	451	5207	251	315	223	205	2362	114
	Oct 21-31	856	607	556	6527	312	388	275	252	2961	142
	Nov 01-10	13	9	8	97	4	6	4	4	44	2
Total	11 Prds	9749	6917	6337	74160	3556	4422	3138	2874	33639	1613
1988	Jul 01-10	13	9	8	98	4	6	4	4	44	2
	Jul 21-31	570	403	369	4274	205	259	183	167	1939	93
	Aug 11-20	243	172	158	1871	90	110	78	72	849	41
	Aug 21-31	5012	3555	3256	38018	1825	2273	1612	1477	17245	828
	Sep 01-10	31275	22104	20226	233765	11266	14186	10027	9175	106036	5110
	Sep 11-20	974	688	630	7282	352	442	312	286	3303	160
Total	6 Prds	38087	26932	24647	285308	13742	17276	12216	11180	129416	6233
1989	Aug 01-10	24	17	15	176	8	11	7	7	80	4
	Sep 21-30	10	7	6	75	4	5	3	3	34	2
Totals	2 Prds	34	23	21	251	12	15	11	10	114	5
1990	Sep 11-20	23	16	15	172	8	10	7	7	78	4
	Sep 21-30	33	23	21	254	12	15	10	10	115	5
	Oct 01-10	20	14	13	154	7	9	6	6	70	3
Total	3 Prds	76	54	49	580	27	34	24	22	263	12
Total	58 Prds	78805	55834	51129	595139	28595	35746	25326	23192	269955	12971

The Nez Perce forest has the largest land base in the SBW and accounted for 73 percent of the total wilderness emissions; the Bitterroot 23 percent and the Clearwater just four percent.

Emissions for the 14 years totaled 35,746 Mg. Yearly emissions ranged from essentially none in 1977, 1978, and 1980, to over 17,000 Mg in 1988. The mean for the 14 year period is about 2,550 Mg/year.

SBW fire emissions, like their associated fire size distribution are highly skewed with a few fire years accounting for large portions of the data. Table 2 ranks the fourteen years for their percentage contribution to total particulates. The ranked quartile values are approximately 12, 250, and 3,400 Mg/yr.

Table 2. Ranking of years contribution to total emissions.

Year	PM Total Mg	Percent of Total	Cumulative Percent
1988	17276	48.3	48.3
1979	5589	15.6	64.0
1987	4422	12.4	76.3
1986	3031	8.5	84.8
1981	2827	8.0	92.9
1985	1975	5.5	98.4
1984	366	1.0	99.4
1982	101	0.3	99.7
1983	63	0.2	99.9
1990	34	0.1	100.0
1989	15	.0	100.0
1977	0	.0	100.0
1978	0	.0	100.0
1980	0	.0	100.0

Three years (1979, 1987, and 1988) accounted for over seventy-five percent of the particulate emissions. Six years (add 1986, 1981, and 1985) produced over ninety-eight percent of the particulates. Four consecutive and recent years, 1985 through 1988 have produced about 75 percent of the total emission over the period of this study.

Forty-eight percent of the total emissions during the fourteen years emissions were produced in 1988, and eighty-two percent of **those** emissions were produced in a single ten day burning period (September 1st to September 10th). **Almost forty percent of the total wilderness smoke emissions were produced by wildfires in one ten day period in 1988.**

Although 1988 was an impressive fire season in the Selway, another perspective is worthwhile. Total emissions from 91 fires (24,000 ha) were less than those estimated by Ward and Hardy (1991) for the **24-hour, 23,000 hectare run** of the 1967 Sundance Fire in Northern Idaho (19,000 Mg PM; 22,626 ha). They also estimated a 1988 United States total of 1.7 million Mg of particulates. The SBW particulate production in 1988 represented just one percent of the total particulates produced from biomass fires in 1988.

Over all fire regimes and burn intensities, SBW fires (both prescribed natural and

wild) averaged PM emissions of 589 Kg/ha burned (526 lbs/ac). A recent paper (Hardy and others, in prep) describes PM2.5 emissions from a major wildfire-- the 72 day, 38,000 hectare Silver Fire in Southwestern Oregon (September, 1987). PM2.5 emissions were modeled over a 58 day period. Modeled values were compared with airborne measurements of smoke from the fire. They describe an overall PM2.5 emission of 617.5 Kg/ha and conclude that PM2.5 emission factors are more dependent on fire characteristics (i.e. the intensity/combustion efficiency relationship) than on fire size. The SBW PM2.5 overall emission was estimated at 382 Kg/ha (341 lbs/ac), about 60 percent of that estimated on the Silver Fire.

Documentation of Smoke in the Bitterroot and Missoula Valleys

The main emphasis of our portion of this study was to document the occurrence and duration of valley smoke events as related to fires and emission estimates in the Selway-Bitterroot Wilderness. We had hoped to be able document smoke impacts around the specific communities of Darby, Hamilton, Stevensville, Lolo, and Missoula, but quantitative measurements of smoke were not available at either a local or regional level. Although the Missoula County Health Department maintains several air quality stations in the Missoula valley, they do not systematically archive data outside the pollution season (generally November through March). They do record 'exception' violations to state particulate standards. An 'exception' is a particulate violation generally due to natural causes (dust storm, forest fire, etc.). The last exception in Missoula was the eruption of Mt. St. Helens. Neither the State of Montana, nor Ravalli County has any consistent air quality monitoring and data archiving in the Bitterroot Valley.

Three sources were used to **qualitatively** document smoke episodes for the period 1960 through 1990: weather observations from the Missoula Airport; original climate forms from the cooperative station network (NOAA, Climate Analysis Center); and past issues of the Ravalli Republic, published in Hamilton, Montana.

For the cooperative station network, Arnold Finklin went to the State Climate Office in Bozeman to research the daily notes on original forms for stations at Darby, Hamilton, Stevensville, and Philipsburg. Only Hamilton had any records of smoke in the original forms. For the Missoula Airport, Finklin researched published observations looking for smoke as a weather element and noted the hour(s) of smoke, visibility and general wind.

We cross referenced sources to ensure that for days noted as having valley smoke, it could be from SBW fires. For example, the 1990 Gird Point fire in the Sapphires Mountains east of Hamilton caused smoke to be reported for several days in July from the Missoula Airport. Likewise, in mid August of 1990, Missoula Airport reported smoke while the Ravalli Republic (8/9) reported "smoke filling Bitterroot Valley skies is from fires on the Nez Perce and Boise National Forests. The Cub Point fire on the Nez Perce may be spilling smoke into the valley through the Lost Horse and Lick Creek drainages." Then on the 15th of August reports "Bitterroot fires few and far between but smoke from Idaho (Salmon and Payette National Forests) filling Bitterroot skies... Fire activity on the Bitterroot Forest has been light for the past few days but valley skies have been filled with smoke from wilderness fires on the Salmon and Payette National Forests." Finally, the emissions log shows no significant production until September of 1990.

Similar incidents were noted in 1989 ("smoke which drifts into the valley each evening is coming from... Payette National Forest.") and 1985 ("smoke from Gibbons Pass fire has been creating hazards on Lost Trail Pass.").

Figure 2 shows the number of days with documented smoke (bars) in either the Missoula or Bitterroot Valleys for the period 1960 through 1990. The chart is divided into two halves. The left portion is 12 years of full-control policy (1960-1971). The right portion is 19 years of prescribed-fire policy (1972-1990), with the five years of "Whitecap only" also marked. The solid line on each half is the cumulative number of smoke days for each policy period. Shaded areas (starting in 1977) show estimated yearly total emissions.

The documented smoke events probably represent minimal values; certainly occasional days of minor smoke could be missed, but we feel all occurrences of significant smoke have been identified. (The actual number of days could certainly vary also.)

Frequency

Over the 31 years, 12 years (40 percent) had one or more days of forest fire smoke in **either** the Missoula or Bitterroot valley. During the 12 years of full fire suppression from 1960 to 1971, six years (50 percent) had one or more days of smoke. During the five years of the prescribed natural fire policy in the Whitecap drainage (1972-1976), one year (20 percent) had smoke. Finally, during the recent 14 years (1977-1990) of prescribed natural fire policy in the entire SBW, five years had documented smoke occurrence (about 35 percent).

These limited data suggest no major differences in the occurrence of significant smoke events under total suppression and prescribed fire periods. Overall, smoke incursions from wilderness fires probably occur about twice as often in the Bitterroot valley as they do in the Missoula valley.

Duration

The best documentation of valley smoke character and duration was obtained from the original climate reports from Hamilton. These notes are only specific to the Hamilton ares but give a good indication of the character of most significant smoke episodes. I also suspect since there are only seven over the years, they may have been among the most significant smoke episodes. This information is tabulated in table 3 along with the corresponding weather summary for the day from the Missoula airport. Seven years from 1960-1990 (about 25 percent) were noted with smoky periods. The longest durations were about ten days in 1961 and 1988, with minimums of two to three days in 1973, 1979, and 1981. This maximum value of about ten days agrees with an analysis of potential run lengths of poor dispersion conditions for the Moose Creek Ranger District (Keown 1978; 1984, Furman, 1979) which estimated that over 95 percent of poor dispersion periods would be ten days or less, and 60 to 80 percent of them would be three days or less. Rain was not a factor in terminating any of the duration observations in table 3.

Table 3. Notes from Hamilton Climate Station and Missoula Airport Valley Smoke

Year	Date and Hamilton Climate Station Reference	Missoula Wx & Visibility	#Days
1960	Jul 21 - Extremely Smoky Jul 22 - " " Jul 23 - " " Jul 24 - Still Smoky Jul 26 - Some Smoke	20 mi, smoke 15-20 mi, smoke all quads 20-30 mi, smoke, 10000 ft Smoke distant SE No mention	5
1961	Aug 3 - Smoky Conditions Aug 4 - Numerous Forest Fires. Air Smoky & Hazy Aug 5 - " " " " " " Aug 6 - Very Smoky Aug 7 - " " Aug 8 - " " Aug 9 - " " Aug 10 - Extreme Low Hanging Smoke Aug 11 - " " " "	No mention 6-10 mi, Sky Obscure w/K No mention 35 mi, smoky south 20 mi, smoky south 8-10 mi, smoky south No mention No mention 20 mi, smoky	9
1967	Aug 24 - Haze Conditions, Forest Fire Smoke Aug 25 - " " " " " Aug 26 - " " " " " Aug 27 - " " " " " Aug 28 - Haze Conditions, Clearing Aug 29 - Clear	12-15 mi, smoky No mention " " " " " " 20 mi, smoky morning	5
1973	Aug 16 - Forest Fire Smoke Haze Aug 17 - " " " "	No mention " "	2
1979	Aug 5 - Smoky Aug 6 - "	No mention " "	2
1981	Aug 27 - Forest Fire Smoke Aug 28 - " " " Aug 29 - " " "	12-25 mi, smoky all day 12-25 mi, smoky south No mention	3
1988	Aug 26 - Heavy Smoke in Valley from Fires Aug 27 - Nice Day, Still Smoky Aug 28 - Sunny Above the Smoke Aug 29 - Very Warm with Smoke Aug 30 - Less Smoke In Valley Month Note: First forest fire smoke taking spotlight around the 21st and pervading the valley most of the time.	No Mention 20-30 mi, smoke SW-W 15 mi, smoke south 5 mi am, 20 mi pm, smoke S No mention	5-9

The smoky days in 1973 were probably attributable to the Fritz Creek fire in the Whitecap drainage of the SBW. The Fritz Creek fire was the first prescribed natural fire of size under the prescribed fire management plan in the SBW. Its 40 plus day lifecycle is documented in the Environmental Statement for the SBW Management Plan and also discussed by Mutch and Briggs (1973). Mutch observed frequent morning inversions in the Whitecap drainage with interdrainage visibility reduced to about one mile on the morning of August 15th. The inversions would break up in the early afternoon, giving rise to the fire activity of the afternoon burning period. The smoke plume from afternoon burning was visible on several occasions over the Bitterroot Valley, about 28 air miles east of the fire. This smoke probably did not settle into the valley, hence the haze description versus low hanging smoke as noted in 1961. The Fritz Creek Fire was at about 250 ha (600 ac) at this time. On the 15th, a spot fire from Fritz Creek ignited the Snake Creek Fire, a wildfire which burned 650 ha in a couple of days and more than likely contributed, or even caused the reported valley smoke. During this period there was no mention of smoke from the Missoula Airport. The Ravalli Republic carried stories of the wilderness fires but made no mention of smoke in the Bitterroot valley.

Visibility and Particulate Concentration

There were no measurements of particulate concentrations available for this study and measurements of visibility were available only at Missoula Airport. Coleman (1973) reports of work by Charlson (1968) that relates total suspended particulate (TSP) concentration and visual range:

$$V = 750/C$$

where C is the concentration (ug/m^3) and V is the visual range in miles. This relationship assumes relatively well aged aerosol, which would generally be the case for smoke transported from the wilderness to the Missoula Valley. This relationship was scaled such that at a concentration of 150 ug/m^3 (the secondary standard) the visual range is five miles (air operations may be affected below this value). The secondary standard is a national (EPA) standard that "specify those levels necessary to protect public welfare from any known or anticipated adverse effect."

Table 3 also tabulates visibility and smoke reports at the Missoula Airport for the same day smoke was noted at the Hamilton climate station. Only twice did the visibility drop to near the five mile (150 ug/m^3) standard (August 4, 1961 and August 29, 1988). Visibility was generally lowest in the morning and greater in the afternoon as daytime heating increased atmospheric mixing. Most of the time visibility was in the 10 to 20 mile range (16-32 km) which approximates particulate concentrations of 75 to 40 ug/m^3.

For Missoula, these estimates comprise all smoke in the valley, some of which could be local industrial smoke (especially in the 60's), or smoke from other airsheds that drain into the Missoula valley.

Multiple Large Fires and Seasonal Progression

Figures 3 through 8 display seasonal profiles of the six years from 1977 to 1990 that had significant smoke emissions (1979, 1981, 1985, 1986, 1987, 1988). The seasonal life cycle of each fire that grew to over 40 ha (100 ac) in size is plotted. Each fire is marked as prescribed natural fire (dashed connection) or wildfire (solid connection). It also displays estimated particulates by 10-day period (area under curve), and denotes which 10-day periods had documented smoke (short bars) in the Bitterroot or Missoula valley. The bars indicate only that smoke was observed; no duration or concentration is implied. Particulate scales are the same (0 to 3,000 Mg) on all figures except for 1988 (figure 8; 0 to 15,000 Mg). Generally the wildfires in these figures were fought under a limited suppression policy and burned as long as the years prescribed fires.

These figures illustrate similar seasonal patterns and represent, in total 66 of the 137 fires (48 percent) in the master list. Recalling the master list itself contains about 12 percent of the total fires, the figures represent about 5 percent of the total SBW fires. These fires generally burned for at least 20 (often more than 30) days before entering their peak activity period. Active burning for most years was limited to less than two 10-day burning periods and except for 1986 and 1987 was mostly confined to one 10-day period.

The story of 1987 is rather baffling. It was a relatively high fire occurrence year (80 fires). It had 12 prescribed natural and 2 wild fires over 40 hectares, including the Bear Fire which burned 3,000 ha (7500 ac) over the course of the summer. It had comparable amounts of particulate production with other active fire years (except 1988) yet had no observations of significant valley smoke in either Hamilton or Missoula. The most striking difference between 1987 and other years is the late onset of the active burning (September 1st) with a gradual decrease of activity through October.

Attempt to Correlate Upper Air Map Types with Wilderness Emissions and Valley Smoke

Finklin used an upper air (500 mb) map type classification system he developed for his climate studies of the Selway-Bitterroot (Finklin, 1976; Finklin, 1983) to classify maps during high particulate production periods from 1979 through 1990. We used Finklin's map types because of the extensive conditional climatology that he developed in association with them. There was no evidence of consistent association with map type with either emission production or valley smoke episodes. If any association could be drawn it would be a TR map type (trough to the west, ridge to the east) over the wilderness was classified for three of eleven periods of active fire behavior. This type of map could be conducive to frontal instability, and during August and September, passage of dry cold fronts, which can be conducive to very active burning periods.

Modeling Dispersion of Smoke From Wilderness Fires

Air quality modeling over mountainous terrain is a difficult, data intensive task despite an available suite of dispersion models. Application to this study is further complicated by 500,000 hectares of highly complex terrain covering three major topographic sectors separated by long extended high elevation ridges. Potential emissions from fires vary greatly in number, intensity, location and duration. And there are two applications to consider--dispersion within local SBW drainages and long-distance transport to areas outside the wilderness.

Long distance transport models for emissions in complex terrain such as TAPAS (Topographic Air Pollution Analysis System (Fox, Dietrich and Childs, 1984), Complex I (EPA, 1981) and PUFF (PNW 1991, need citation) all require some degree of atmospheric sounding data and gridded topographic information, both of which were outside the initial scope of this study. However, a soon to be released update of PUFF contains gridded data topographic data for Montana and Idaho (pers. comm., Colin Hardy). PUFF, which runs on a PC, could be used with our emissions data and climatological upper air soundings (data recently purchased by RWU 4401), to model long distance transport for some representative prescribed fire scenarios. The results of these modeled scenarios could be compared to documented smoke events in the Missoula/Bitterroot valley for both duration and visibility.

For local inter-drainage dispersion simulation, I attempted to use VALBOX. VALBOX (Sestick and others 1992) is a mass conserving ventilated valley box model where mountain valley terrain is represented by one or more connected boxes through which air flows. Box sides are composed of the mountain sides and the top is the mixing

height. Box models best represent dispersion during stable atmospheric conditions where inversions are present. These conditions often comprise the worst air pollution conditions in mountainous terrain. VALBOX does not consider smoke export from an area through plume entrainment into the free air winds. VALBOX was used to estimate local emissions from a 'stylized' fire in the visual range of Hells Half Acre lookout, which was established in 1992 as a air quality visual control point (pers. comm., Ann Acheson). From the lookout, four visual targets within the wilderness are monitored with photographs, three times/day (0900, 1200, 1500). The targets are:

1. Wounded Doe Ridge, 82 Km North-Northwest on a bearing of 339 degrees,
2. Graves Peak, 84 Km North on a bearing of 354 degrees,
3. Indian Hill, 17 Km North-Northeast on a bearing of 21 degrees, and
4. El Capitan, 44 Km North-Northeast on a bearing of 24 degrees.

I chose the Saddle Gulch prescribed natural fire (SBW Master Fire List, Fire #3) to illustrate the methodology of VALBOX. The Saddle Gulch fire started the 8th of September in the Indian Creek drain about halfway between Hells Half Acre Lookout and Indian Hill. It burned 19 ha (48 ac) in one 10-day burning period and was declared out October 30th. It was a fairly balanced mixture of crown fire (7 percent), lethal underburn (35 percent), non-lethal underburn (30 percent) and unburned (28 percent). The topography for this fire is the east-west Indian Creek drainage east of Schofield creek. Using the overall SBW emission factor of 589 Kg/ha (reference page 7), the fire would have emitted 11,191 Kg of particulates.

West Fork Ranger station weather recorded 1.46 inches of rain between August 21st and September 8th and had 10-h timelag fuel moisture ranging from 12 to 48 percent. After the fire started, there was no precipitation during the 10-days the fire was most active. The table below summarizes the North Fork weather observations from the date of ignition through the fires first burning period. Hells Half Acre stopped weather observations on 31 August.

North Fork Weather Obs for Saddle Gulch Fire

MMDD	DB	RH	WS	1-h	MXT	MNT	MxRH	MnRh	Ppt
0908	86	16	5	12	88	38	83	16	.00
0909	78	22	8	9	78	48	73	26	.00
0910	60	31	2	16	90	37	93	31	.00
0911	62	26	3	15	77	27	99	26	.00
0912	67	18	2	15	70	28	96	18	.00
0913	71	25	4	8	74	28	95	25	.00
0914	81	16	3	6	84	27	91	16	.00
0915	94	13	4	6	96	28	88	16	.00
0916	93	16	4	6	95	34	73	19	.00
0917	82	17	2	6	90	34	85	17	.00
0918	84	16	4	6	87	35	86	16	.00
0919	81	14	4	5	89	34	88	14	.00
0920	82	15	3	5	84	35	92	15	.00

I assumed the fire did most if it's burning starting on the 15th when the temperature reached 94 and the humidity dipped into the low teens. I further assumed it

and did 80 percent of its burning during three, 5-hour burning periods from 1300 to 1800 on the 15th, 16th, and 17th of September, and released the other 20 percent of its particulates during the other 57 hours on those three days.

Appendix D contains a complete list of the simulation inputs and results, which are recapped here. I estimated the volume of the box (approximately 2 miles long, 1/2 mile wide at the bottom, and 3 miles across at the ridge tops) at 500,000 million cubic feet. The mixing level (above the valley floor) was set at 2500 feet (approximately the height of the canyon walls above the floor) for the daytime and 500 feet for the night time. (Source: average monthly mixing heights, USFS Fire Laboratory, Missoula, July 1978 through June 1979.) I used light (2 mph) down valley winds from midnight to 0800, calm from 0800 to 0900, light (1 or 2 mph) up valley winds from 0900 to 1200, and 4 mph up valley winds from noon until 1800, then an hour of calm, and then light downslope winds until midnight. The winds were similar for all three days of the simulation.

VALBOX requires emission rates in grams/second. The 11,191 kg in total emissions converts to emission rates of 166 g/s for the three 5 hour afternoon burning periods, and 11 g/s for other periods. Initial particulate concentrations in the simulation were zero. Table 3 summarizes the VALBOX total suspended particulate (TSP) estimates for this example for four time-averages, 1, 3, 8, and 24 hours.

Table 3. TSP estimates for three days of the 1979 Saddle Gulch Fire.

VALBOX TSP (ug/m^3) and Visibility (mi) Estimates for Saddle Gulch Fire, September 1979				
Box Values are TSP/Vis	1 Hr Avg	3 Hr Avg	8 Hr Avg	24 Hr Avg
Average	20/38	20/39	21/36	22/34
Std Dev.	15.	12.	9.	5.
Minimum	0/unl	3/unl	8/94	15/50
Maximum	64/12	49/14	40/19	28/27

For this example, which is probably very typical of a smaller, late season prescribed natural fire, the maximum hourly TSP (64 ug/m^3) occurred around 1800 of the 16th (second burn day) when a afternoon wind dropped from 4 mph to 1 mph. This would correspond to about 12 (20 km) miles visibility. The 24-hour average of 22 ug/m^3 (34 mi, 54 Km visibility) is only about 15 percent of the EPA secondary standard. (Which is also the primary standard in Montana.) I have no sense of reasonableness of these numbers.

Once I got the feel for VALBOX (it is very sensitive to the box structure and it is very easy to get negative concentrations) it is straight forward to estimate other sets of emission parameters, as long you we keep in mind its limitations-- interdrainage smoke dispersion under light winds and stable atmospheric conditions. VALBOX seems most applicable to the smaller, late season fires where major fire runs do not occur and most of the smoke remains within the drainage.

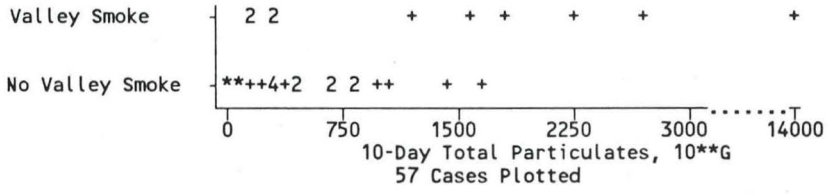
10-Day Particulate Production And The Occurrence of Valley Smoke Events

I do not feel we have been able to reliably estimate valley particulate concentrations from wilderness emissions through either measured or modeled air quality. However, we have been able to reasonably document the occurrence of valley smoke over a 31 year period, and estimate wilderness emissions for a 14 year period.

Table 4 summarizes all the information so far presented. The first section of the table is for the period 1972 through 1990--the period of active fire management in the Selway-Bitterroot. The second part simply tabulates historical occurrences of smoke from 1960 through 1971. The first column section tabulates the yearly summaries--wildfires and area; prescribed natural fires and area; and total particulates. Subsequent column sections tabulate the 10-day total particulate production from July 1 through November 10 and, if valley smoke was observed, the source(s). Ten-day periods were used for two reasons. First to provide workable timeframe for reconstructing the fire growth estimates--daily was unreasonable, and secondly to provide a common basis for climatic summary programs (Bradshaw and Fischer, 1984, Furman 1979) that we anticipated using for this study.

Figure 9 is a scatter chart of 10-day particulate production from 1977 to 1990 and the occurrence of a valley smoke event as taken from table 4. (Only periods with non-zero emissions are included. A plus (+) indicates a single occurrence, an asterisk (*) denotes 10 or more occurrence, and the numerals denote 2 or 4 occurrences.) A smoke event was defined as reported smoke for at least one day in a 10-day period, and for the scatter chart, assumes a value of yes or no. Figure 9 indicates a transition range between 1,000-1,500 Mg/10-day period in which smoke may occur, and above which are almost certain to occur. It also documents four smoke events that occurred during relatively low emission periods (100-250 Mg/period).

Figure 9. Scatter chart of the occurrence of 1 or more valley smoke days in a 10-day period versus total particulate estimate for the period (non zero periods only)



Defining a smoke event as a dichotomous variable lends itself to a logistic regression model as a method to relate emission production to the occurrence of valley smoke. The same data set was used in a logistic regression routine to estimate the occurrence of smoke as the dependent dichotomous variable. The independent variable was 10-day total particulate emissions. The statistical package STATISTIX was used. The following is the model output summary.

Unweighted Logistic Regression of Smoke (Yes/No)

Predictor Variable	Coefficient	Std Error	COEFF/SE	P
Constant	-2.7971	6.07E-01	-4.61	.0000
PMTOTAL	2.0032E-03	6.44E-04	3.11	.0030

```
Degrees of Freedom      55
Deviance              36.18   P value  0.9766

Cases Included 57   Missing Cases 0
```

The P value of 0.9766 indicates the model fits the data quite well as would be expected from the scatter chart. Figure 10 plots the expected probability of smoke as a function of PMTOTAL (10-Day Total) as it ranges from 0 to 3,000 Mg. The regression equation is:

$$P(smoke) = 1./(1. + e^{(-2.7971 + .0020032 * PMTOTAL)}).$$

This equation provides a framework to estimate frequency of valley smoke during primeval periods if estimates could be made of 10-day emissions for primeval periods.

Figure 10. Selway Bitterroot Wilderness Area
Probability of Significant Valley Smoke in a 10-Day Period
As a Function of 10-Day Particulate Production

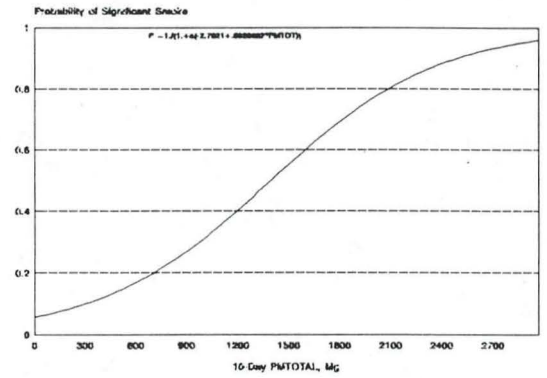


Table 4 summarizes all the information so far presented. The first section of the table is for the period 1972 through 1990--the period of active fire management in the Selway-Bitterroot. The second part simply tabulates historical occurrences of smoke from 1960 through 1971.

Table 4. Summary of Wilderness Fire Occurrence, Emissions, and Smoke Occurrence in the Bitterroot or Missoula Valleys.

	Fire Summary for Year			Estimated Emissions by 10-Day Periods, 10**6 Grams. Documented Smoke Episodes Are Noted By Source Reference (M=Missoula Airport, C=Hamilton Climate Records, R = Ravalli Republic)												
Year	Wild Fires	Rx Fires	PM Total 10**6 G	Jul 1	Jul 11	Jul 21	Aug 1	Aug 11	Aug 21	Sep 1	Sep 11	Sep 21	Oct 1	Oct 11	Oct 21	Nov 1
1972	68 fires 7 ha	1 fire 0 ha	*						M							
1973	71 fires 749 ha	3 fires 506 ha	Fritz Ck Not Estimated					R	R							
1974	39 fires 1 ha	1 fire 0 ha	*													
1975	27 fires 1 ha	6 fires 1 ha	*													
1976	17 fires 0 ha	3 fires 0 ha	*													
1977	12 fires 0 ha	0 fires 0 ha	*		M											
1978	7 fires 0 ha	1 fire 0 ha	*													
1979	66 fires 25 ha	25 fires 12703 ha	5589	28	113 M	370	2703 C	1451	60	224	70	551		20		
1980	2 fires 0 ha	3 fires 0 ha	*													
1981	82 fires 2210 ha	26 fires 2503 ha	2872			32	96	149 M	1789 M,C,R	262	544					
1982	6 fires 1 ha	22 fires 198 ha	101			4			91			6				
1983	3 fires 259 ha	24 fires 0 ha	63						63							
1984	10 fires 16 ha	71 fires 590 ha	366				8	48	265	45						

	Fire Summary for Year			Estimated Emissions by 10-Day Periods, 10**6 Grams. Documented Smoke Episodes Are Noted By Source Reference (M=Missoula Airport, C=Hamilton Climate Records, R = Ravalli Republic)											
Year	Wild Fires	Rx Fires	PM Total 10**6 G	Jul 1	Jul 11	Jul 21	Aug 1	Aug 11	Aug 21	Sep 1	Sep 11	Sep 21	Oct 1	Oct 11	Oct 21	Nov 1
1985	91 fires 3080 ha	14 fires 82 ha	1975	4	250 M	1587 M	3	68		64						
1986	41 fires 3715 ha	26 fires 1690 ha	3031	9		22	753	1189 M	991	68						
1987	16 fires 1696 ha	65 fires 6080 ha	4422	M	35		293	27	40	28	1613	897	779	315	388	6
1988	82 fires 23907 ha	9 fires 210 ha	17276	6		259 M		110	2273 M	14186 M	442					
1989	90 fires 39 ha	0 fires, program review	15			M	11 M	M				5				
1990	57 fires 25 ha	14 fires 69 ha	34	M		M	M	M			10	15		9		
1960				M		M,C										
1961						M	M,C	M	M							
1962																
1963					M		M,R									
1964																
1965																
1966																
1967					M		M	M	C							
1968																
1969																
1970					M				M							
1971						M	M		M							

Discussion and Conclusion

We have documented the occurrence and character of smoke incursions in the Bitterroot and Missoula Valleys under a period of full fire control and a period of prescribed fire management in the Selway-Bitterroot Wilderness area. We have also looked at estimated smoke emissions (particulates) from fires greater than 4 hectares (10 acres) during the period of prescribed fire management. The smoke impact matrix from the Final Environmental Statement for the Selway-Bitterroot Fire Management Plan is used to draw this information together. The matrix identifies three levels of smoke; minor, moderate, and extreme. This summary discusses the nature and frequency of each level, and the estimated emission production.

Smoke Impact Matrix, Adapted from SBW Final Environmental Statement

Impact Code 0 = Essentially No Impact 1 = Some Impact 2 = Extreme Impact Possible	Minor Smoke: 0 to few fires; of small size and short duration: unstable air favorable for smoke dispersion	Moderate Smoke: few to several fires; at least 1 large and persistent; changeable weather, but air generally unstable	Extreme Smoke: several to many ongoing fires; at least some large and persistent; stable air; climatic conditions favorable for inversions
Social: Users in SBW	0 to 1	0 to 1	0 to 2
Social: Nearby Communities	0 to 1 Smoke might be visible	0 to 1 Smoke might settle for a day or two	0 to 2 Might be prolonged smoke
Economic: Airports	0	0 to 1	0 to 2
Economic: Agriculture	0	0	0 to 1
Economic: Tourism	0	0 to 1	0 to 2

No Smoke

Over fifty percent of the years had no significant smoke. Most years with no smoke had less than 100 Mg (110 tons) particulate emissions for the whole year. It is possible however, to have significant wilderness particulate emissions, but not have valley smoke, 1987 being a case in point. Over 4,400 Mg (4,840 tons) of particulates were generated, but there appears not to have been any significant smoke. The only atypical feature of 1987 was a rather wet July and August with the major particulate production occurring over 40 days from mid-September to late October.

Minor Smoke

Minor smoke impacts are characterized by an occasional day or two of smoky valley haze. Visibilities probably do not drop below 20 miles (40 ug/m^3) and there is little impact on wilderness users or nearby communities. Minor smoke from SBW fires occurs, on the average, about four or five years out of ten. Wilderness particulate production for a 10-day period is almost always less than 100 Megagrams (110 tons).

Moderate Smoke

Moderate smoke impacts are characterized by three to four days of persistent smoke with visiblities dropping to eight to fifteen miles (100 ug/m^3). There may be localized impacts on wilderness recreationists and local communities. Moderate smoke from wilderness fires occurs, on the average, about two or three years out of ten. Wilderness particulate production associated with moderate smoke impacts, for a 10-day period ranges from 500 to 1,500 Mg (550 to 1,650 tons). There were at least two occasions when minor to moderate smoke episodes were noted in the Bitterroot Valley when the smoke was from fires on the Salmon or Payette Forests in Idaho, and on one occasion, definitely from wilderness fires on the Frank Church Wilderness that borders the southern boundary of the SBW.

Extreme Smoke

Extreme smoke impacts are characterized by five to ten days of extended lingering smoke with visibilities dropping below five miles (> 150 ug/m^3), especially during the morning hours. There may be widespread effects on wilderness recreationists and local communities. Extreme smoke impacts from wilderness fires occurs, on the average, about one year out of fifteen. Wilderness particulate production associated with extreme smoke impacts, for a 10-day period are generally greater that 1,500 Mg (1,650 tons). In the thirty-one years examined by this study, the most severe smoke episode in the Bitterroot Valley was probably the first 10-days of August, 1961. Twenty seven years later, at the end of August 1988, was the next worst year. There is no evidence of commercial aviation being affected by extreme smoke events.

A point of interest is that one extreme smoke episode occurred in each fire management regime. However, all fires contributing significantly to the situations were managed as wildfires, although not much active suppression was probably done on the bigger 1988 fires deep in the wilderness.

Smoke During Presettlement Times

The final aspect of this study addresses the character and frequency of valley smoke events during presettlement times.

Cooperative work by the Fire Effects Unit on this study has estimated that primeval emission rates were about 38 percent more than those in the 1972 to 1990 period. (Estimates based on estimated primeval acreages in each fire regime, burnover rates and their associated emission factors.)

I see two methods of employing this information. First, adding 38 percent to the SBW's overall emission rate of 589 kg/ha (ref. page 7) would give a primeval emission rate of 812 kg/ha burned.

This emission rate was applied to the VALBOX simulation program and run through the same box/weather information. Basically, each emission rate was increased by 38 percent VALBOX carried this right through with the TSP estimates and reduced the

corresponding visibility by about 40 percent. Table 5 summarizes the simulation and is valid for within wilderness smoke concentrations.

Table 5. TSP estimates for 38 percent increase in emissions for three days of the 1979 Saddle Gulch Fire.

VALBOX TSP (ug/m^3) and Visibility (mi) Estimates for Saddle Gulch Fire, September 1979				
Box Values are TSP/Vis	1 Hr Avg	3 Hr Avg	8 Hr Avg	24 Hr Avg
Average	28/27	28/27	29/26	30/25
Std Dev.	20.	12.	13.	7.
Minimum	0/unl	4/unl	11/68	21/36
Maximum	89/8	68/11	56/13	39/19

Second we could apply the 38 percent emission increase to the logistic function to estimate the frequency of occurrence of out of wilderness smoke events. My feeling is that the threshold (1000 Mg/10-day period) will remain. It is the frequency that it is crossed that would have changed in a primeval fire regime. This is a particularly appealing approach, since we may be able to categorize the frequency of 10-day periods in a primeval fire regime that approach that threshold. My thinking on this is that we know from this study the frequency of 10-day periods that had between, lets say 750 to 1000 Mg/10-day period. In a primeval regime, this would correspond to 1035 to 1380 Mg/period. Values less than 750 would still be below that apparent threshold, and values over 1000 Mg/period would be way above it. From table 1 there were 5, 10-day periods in this range (out of 58 periods in the study). This would work out to about an nine percent (5/58) increase in smoke events outside the wilderness during a primeval fire regime as compared to this study period.

So, would it be valid to summarize that, with a 38 percent increase in emissions during a primeval fire regime, inter-wilderness emission would have increased by the same amount, but smoke transport out of the wilderness would have increased in frequency about 9 percent? Could we then go so far to say that only 25 percent of wilderness smoke impacts the Missoula/Bitterroot valleys?

Literature Cited

Arno, Stephen F. 1976. The historical role of fire on the Bitterroot National Forest. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. INT-187. 29 p.

Barrett, Stephen 1990. Fire Regimes Classification for the Selway-Bitterroot Wilderness: Analysis of fire history and topo-geographic descriptors by forest type. Final report to cooperative aid agreement INT-88330 (objective A). On file, Intermountain Fire Sciences Laboratory, Fire Effects Research Work Unit. 14 p.

Bradshaw, Larry S.; Fischer, William C. 1984. Computer programs for summarizing climatic data stored in the National Fire Weather Library. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. INT-164. 39 p.

Brown, James K. 1992. Fuel consumption estimates for Selway-Bitterroot fire regime Types. Unpublished report on file, Intermountain Fire Science Laboratory, Fire Effects RWU, Missoula, MT.

Charlson, R.J.; Ahlquist, N.C., and H. Horvath. 1968. On the generality or correlation of atmospheric aerosol mass concentration and light scatter. Atmos. Envir., 2, pp 455-464.

Coleman, Robert D. 1973. Ambient air quality standards for particulate matter in the United States. In: Air Quality and Smoke from Urban and Forests Fires. Fort Collins Colorado, October 1973. National Academy of Sciences, Washington, D.C. pp 162-169.

Environmental Protection Agency (EPA). 1981. Regional workshops on air quality modeling: a summary report. Research Triangle Park. N.C.: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards.

Finklin, Arnold I. 1974. Climate of the Selway-Bitterroot Wilderness. Office Report, Intermountain Fire Sciences Laboratory, Missoula, MT.

Finklin, Arnold I. 1983. Weather and climate of the Selway-Bitterroot Wilderness. University Press of Idaho, Moscow, Idaho. 144 p.

Fox, D.G., D.L. Dietrich, and J.E. Childs. 1984. TAPAS Overview User's/Programmer's guide: TAPAS User's Support Documentation, Report on Contract 28-K2-257. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO 60 pp.

Furman, R. William. 1979. Using fire weather data in prescribed fire planning. Two computer programs. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. RM-63. 11 p.

Furman, R. William and Glen E. Brink. 1975. The National Fire Weather Data Library: What it is and how to use it. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 8 p.

Hardy, Colin C.; Ward, Darold E.; Einfeld, Wayne. 1992. PM2.5 emissions from a major wildfire suing a GIS: Rectification of Airborne Measurements. (In prep).

Keown, Larry D. 1978. Fire management in the Selway-Bitterroot Wilderness. Moose Creek Ranger District, Nez Perce National Forest. U.S. Department of Agriculture. (Revised 1984).

Lieberg, J.B. 1900 The Bitterroot Forest Preserve. Dept of the Interior, U.S. Geol. Sur. 20th Annual report. Part V. Forest Reserves, pp 317-410.

Mehringer, P.J. 1975. Postglacial history of Lost Trail Pass Bog, Bitterroot Mountains, Montana. USDA, Forest Service, Intermountain Forest and Range Experiment Station. (Rest Unknown).

Mutch, Robert W.; Briggs, George S. 1973. The maintenance of natural ecosystems: smoke as a factor. In: Air Quality and Smoke from Urban and Forests Fires. Fort Collins Colorado, October 1973. National Academy of Sciences, Washington, D.C. pp 255-271.

Schroeder, Mark J;, and others. 1964 Synoptic weather types associated with critical fire weather. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 492 p.

Sestak, M.L. and A.R. Riebau. 1988. SASEM: Simple approach smoke estimation model. U.S. Department of Interior, Bureau of Land Management. BLM Service Center, Denver, Technical Note 382. 31 p.

Sestak, M.L.; A.R. Riebau; and M. Matthews. 1991. A tierd approach to smoke management on government lands. In proceedings, 11th Conference on Fire and Forest Meteorology, April 16-19, Missoula, Montana.

Sestak, M.L.; W.E. Marlatt; and A.R. Riebau. 1992. VALBOX: Ventilated Valley Box Model. U.S. Department of Interior, Bureau of Land Management. In preparation.

U.S. Department of Agriculture, Forest Service. 1976. Environmental Statement. Fire Management in the Selway-Bitterroot Wilderness- A proposed policy change Bitterroot, Clearwater, Lolo, and Nez Perce National Forests, Northern Region. UDSA-FS-DES R1-76-12, 226 p.

Ward, Darold E. and Colin Hardy. 1991. Smoke Emissions from Wildland Fires. Environmental International. 17:117-134.

Yancik, Richard F.; Rossopoulous, Peter J. 1982. User's Guide to the National Fire Occurrence Data Library. U.S. Department of Agriculture, Forest Service. Fort Collins, CO. 25 p.

Estimating Emissions and Resultant Smoke...

Figure Captions.

Figure 1a. Selway Bitterroot Wilderness, Prescribed Natural Fire History, 1972-1990.

Figure 1b. Selway Bitterroot Wilderness, Wildfire History, 1972-1990.

Figure 1c. Selway Bitterroot Wilderness, Total Fire History, 1972-1990.

Figure 2. Selway Bitteroot Wilderness, Estimated Total Particulates and Days With Valley Smoke, 1960-1990

Figure 3. Selway Bitterroot Wilderness, 1979 Large Fire Durations, Emissions, & Smoke.

Figure 4. Selway Bitterroot Wilderness, 1981 Large Fire Durations, Emissions, & Smoke.

Figure 5. Selway Bitterroot Wilderness, 1985 Large Fire Durations, Emissions, & Smoke.

Figure 6. Selway Bitterroot Wilderness, 1986 Large Fire Durations, Emissions, & Smoke.

Figure 7. Selway Bitterroot Wilderness, 1987 Large Fire Durations, Emissions, & Smoke.

Figure 8. Selway Bitterroot Wilderness, 1988 Large Fire Durations, Emissions, & Smoke.

Figure 1a. Selway Bitterroot Wilderness Area
Prescribed Natural Fire History
1972-1990

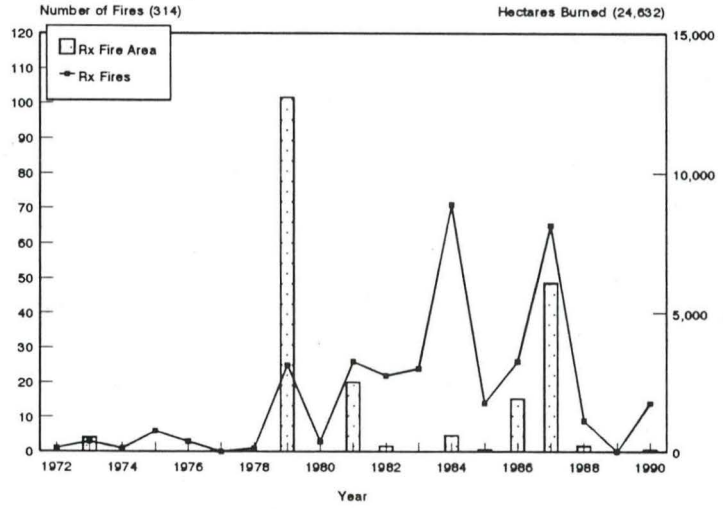


Figure 1b. Selway Bitterroot Wilderness Area
Wildfire History
1972-1990

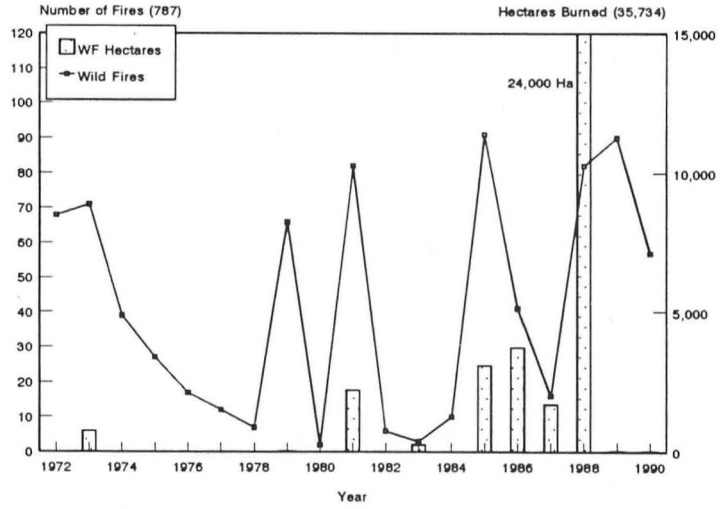


Figure 1c. Selway Bitterroot Wilderness Area
Prescribed Natural and Wildfire History
1972-1990

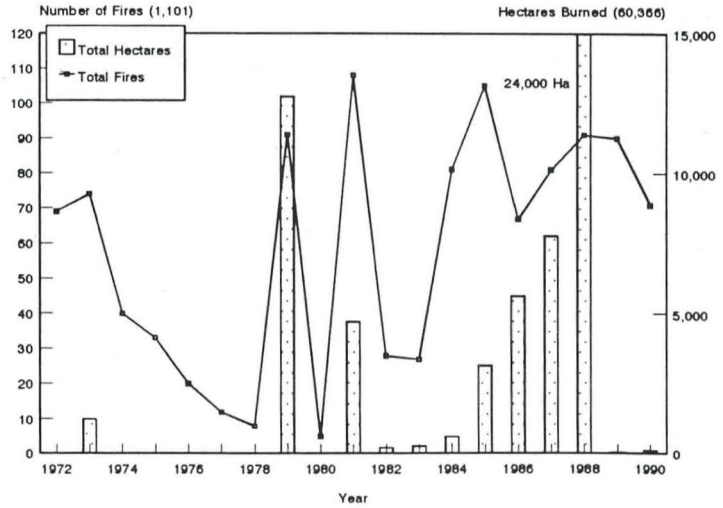


Figure 2. Selway Bitterroot Wilderness Area Estimated Total Particulates and Days With Valley Smoke

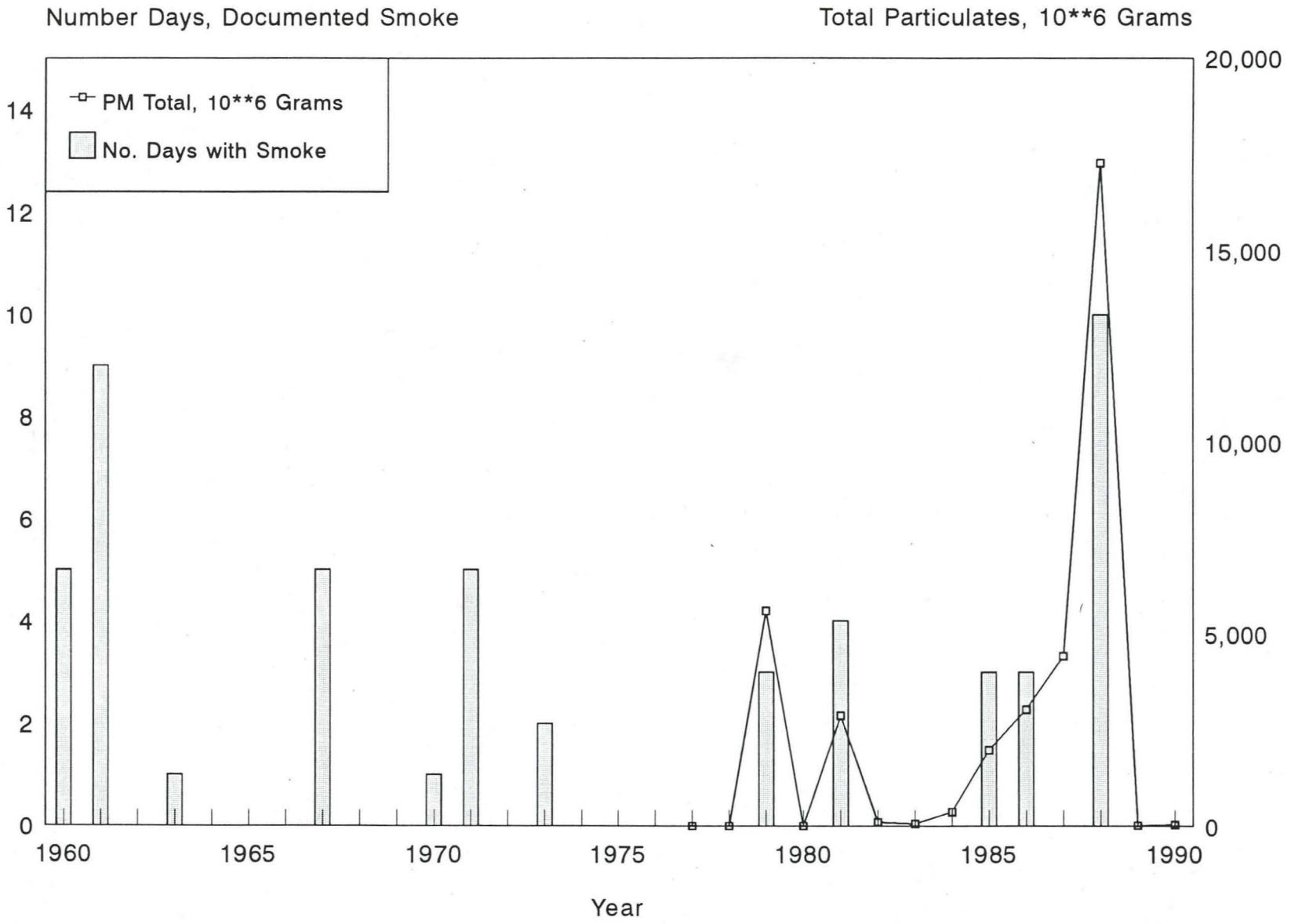


Figure 3. Selway Bitterroot Wilderness - 1979
Large Fire Durations, Total Wilderness Emissions,
And Documented Smoke Episodes

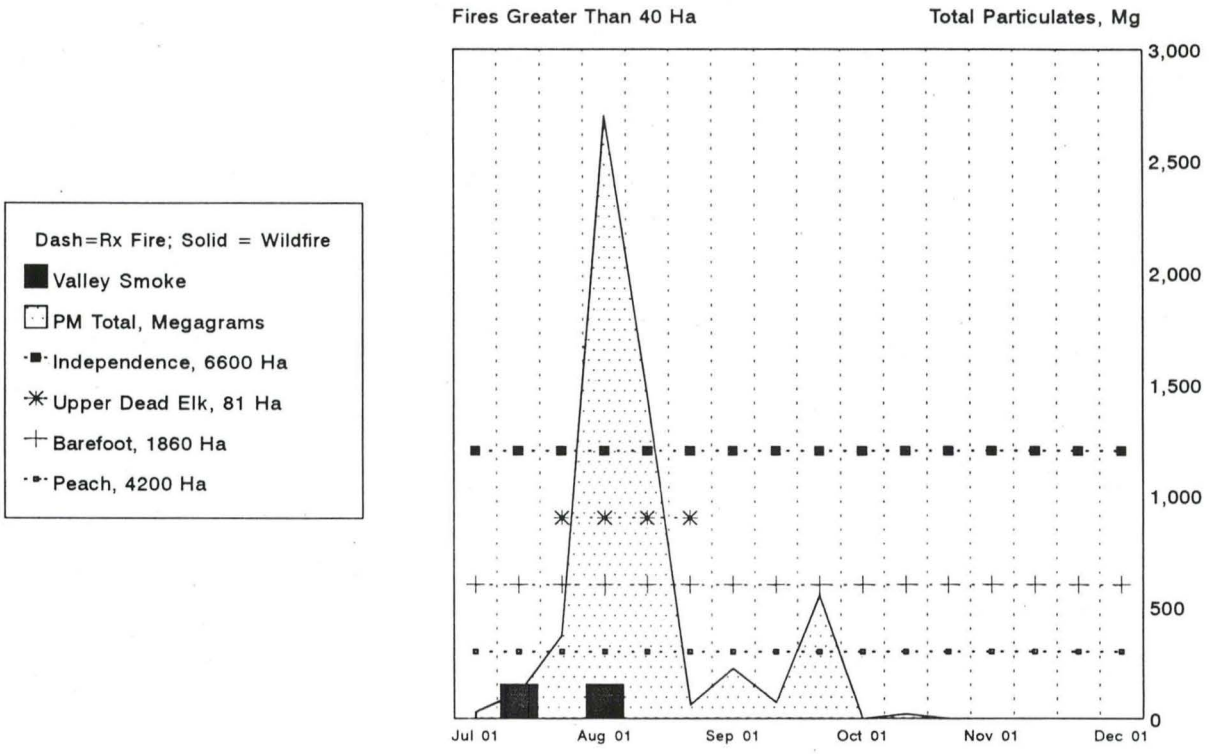


Figure 4. Selway Bitterroot Wilderness - 1981
Large Fire Durations, Total Wilderness Emissions,
And Documented Smoke Episodes

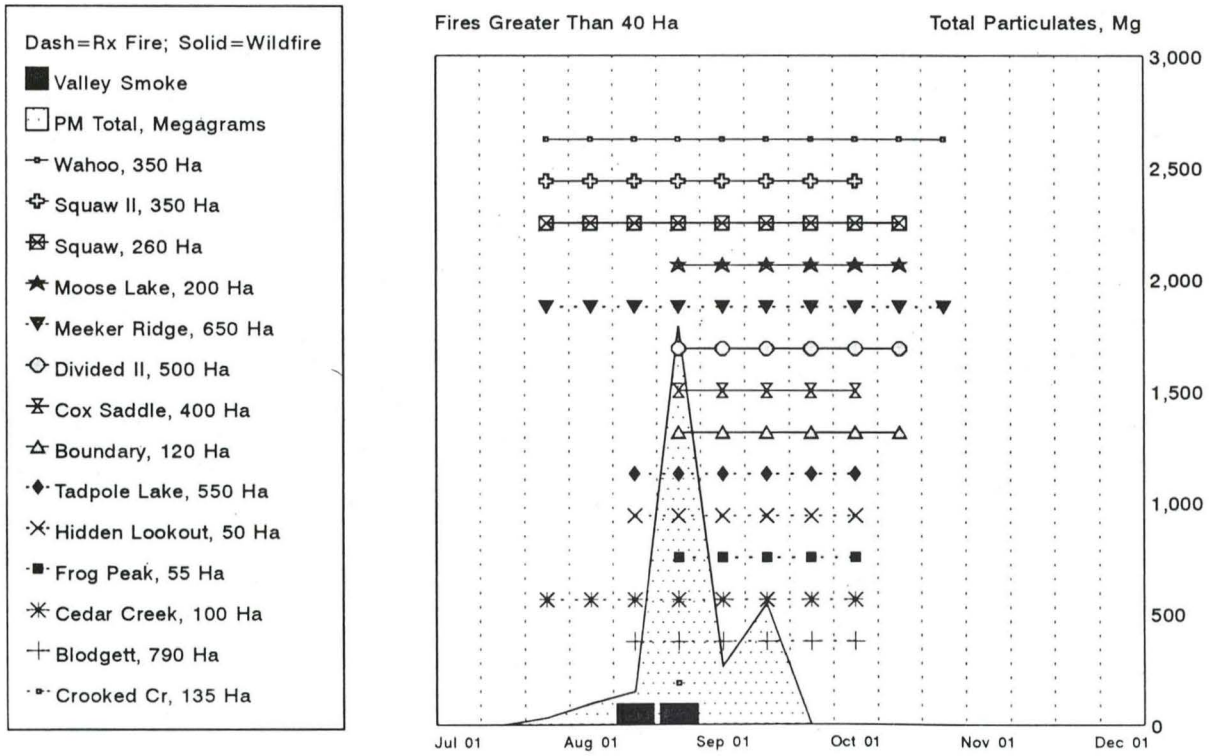


Figure 5. Selway Bitterroot Wilderness - 1985
Large Fire Durations, Total Wilderness Emissions,
And Documented Smoke Episodes

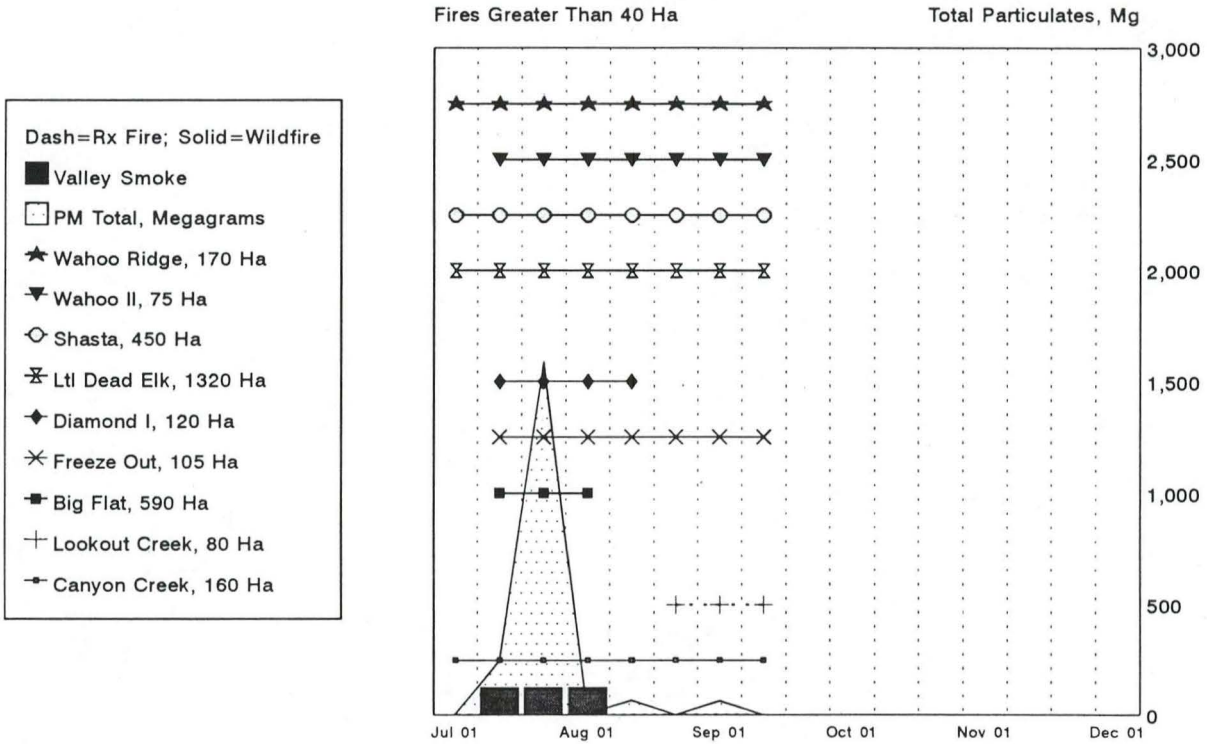


Figure 6. Selway Bitterroot Wilderness - 1986
Large Fire Durations, Total Wilderness Emissions,
And Documented Smoke Episodes

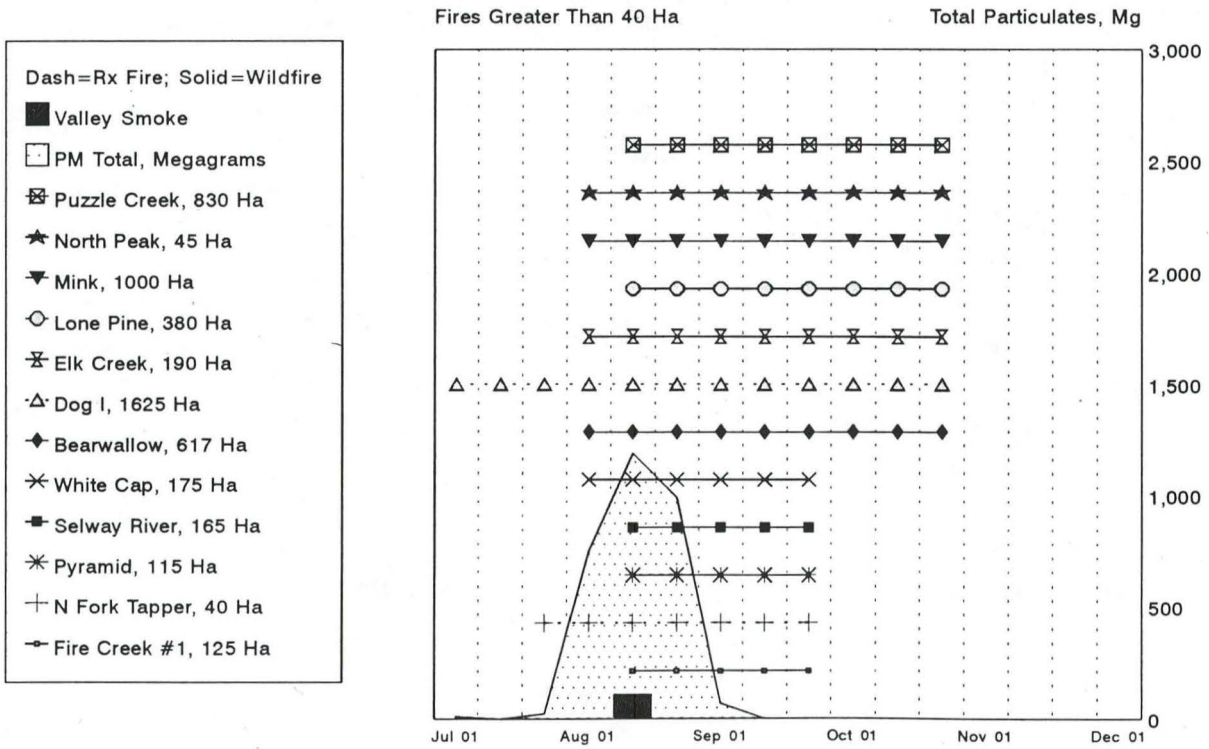


Figure 7. Selway Bitterroot Wilderness - 1987
Large Fire Durations, Total Wilderness Emissions,
And Documented Smoke Episodes

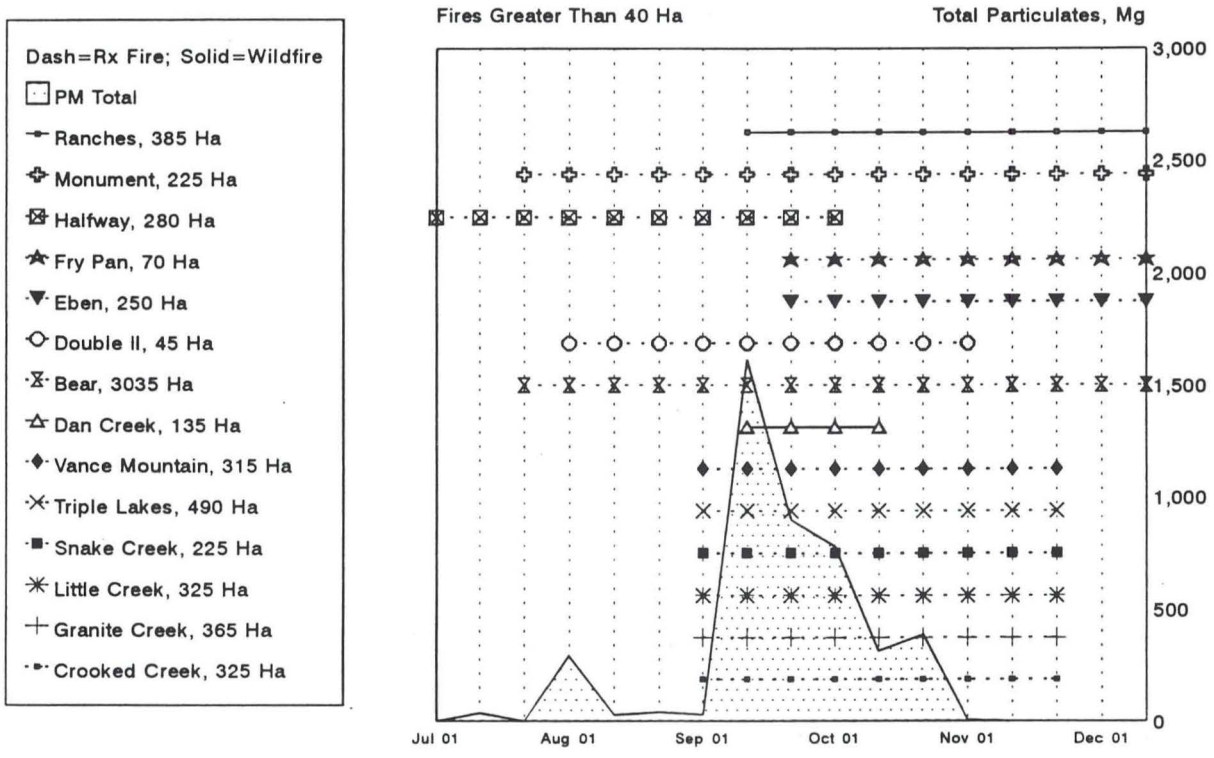
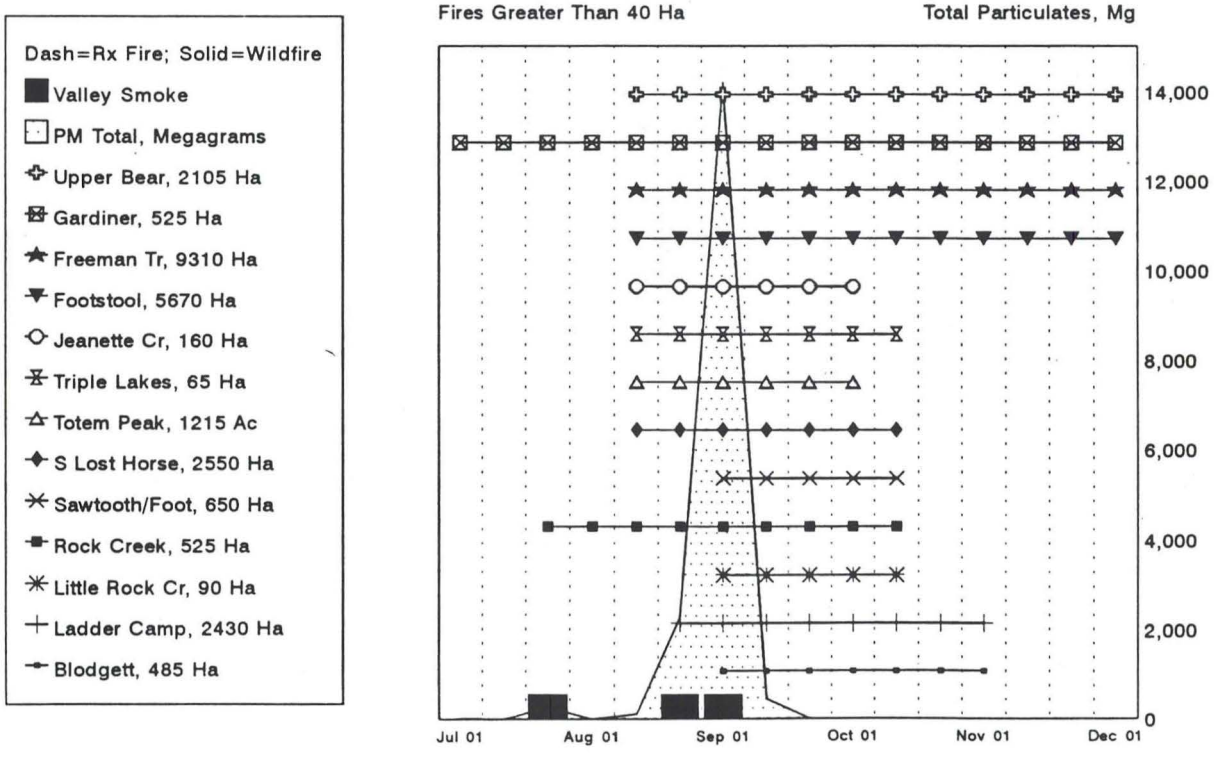


Figure 8. Selway Bitterroot Wilderness - 1988
Large Fire Durations, Total Wilderness Emissions,
And Documented Smoke Episodes



Appendix A: Wilderness Prescribed Natural and Suppressed Wildfire Summary, 1972-1991

Source: Region One, F&AM

WILDFIRES SUPPRESSED AND ACRES BURNED/YEAR/WILDERNESS

Year	Activity	Selway Bitterroot	Ana-conda Pintler	Troy	Cabinet	Scapegoat Danaher	Absoraka Beartooth	Bob Marshall Great Bear	Lolo	FC-RONR	Gospel Hump	Mallard Larkin	Total
1972	#	68	1				3	1		23	22		118
	Acres	18	1				0	0		15	0		34
1973	#	71	5			2	8	32		23	22		163
	Acres	1852	9			0	1	34		17	5050		6963
1974	#	39	1			1	2	10		10	9		72
	Acres	2	75			0	60	4		1	0		142
1975	#	27				1	3	2		15	3		51
	Acres	2				0	0	0		1	0		3
1976	#	17	1				3	4		7	9		41
	Acres	1	0				40	0		0	0		41
1977	#	12	1				6	3		20	10		52
	Acres	1	0				0	0		1	190		192
1978	#	7					4			4	4		19
	Acres	1					0			31	0		32
1979	#	66	2		2	5	12	11		33	19		150
	Acres	63	1		0	1605	32	16		31	10		1758
1980	#	2	1				3	2		14	3		25
	Acres	0	0				20	0		1014	0		1034
1981	#	82	2				7	47		18	12		168
	Acres	5461	478				7	373		11	0		6330
1982	#	6	1			2	2	3		7	7		28
	Acres	2	1			0	0	1		6	3		13
1983	#	3				1	1			12	4		21
	Acres	640				0	0			2	0		642
1984	#	10			2		2	8		18	4		44
	Acres	40			0		0	1		67	45		153
1985	#	91			1		4	10		15	7	3	131
	Acres	7611			30		0	25		6042	6435	0	20,143
1986	#	41			1		3	1		10	10	4	70
	Acres	9181			0		0	1		6119	735	22	16,058
1987	#	16	2				3			15	8	2	46
	Acres	4192	1				27			305	4620	1	9146
1988	#	82	4		3	5	11	36		36	16	11	204
	Acres	59,074	1		0	8	104,101	701		64,395	978	25	229,283
1989	#	90	3			1	1	6		43	24		168
	Acres	96	0			0	1	0		19	329		445
1990	#	57	4			2	9	10		17	17		116
	Acres	62	1			2	918	1		3166	9		4159
1991	#	127						4		26	32	1	190
	Acres	3015						5		3	79	0	3102
Totals	#	914	28		9	20	87	190		366	242	21	1877
	Acres	91,314	568		30	1615	105,207	1162		81,346	18,483	48	299,673

January 1992

PRESCRIBED NATURAL FIRE HISTORY, 1972-1991

Year	Activity	Selway Bitterroot	Ana-conda Pintler	Troy	Cabinet	Scapegoat Danaher	Absoraka Beartooth	Bob Marshall Great Bear	Lolo	FC-RONR	Gospel Hump	Mallard Larkin	Total
1972	#	1											1
	Acres	0											0
1973	#	3											3
	Acres	1250											1250
1974	#	1											1
	Acres	0											0
1975	#	6											6
	Acres	2											2
1976	#	3											3
	Acres	0											0
1977	#	0											0
	Acres	0											0
1978	#	1											1
	Acres	1											1
1979	#	25		1									26
	Acres	31,390		542									31,932
1980	#	3	1		2								6
	Acres	0	0		0								0
1981	#	26	1			2							29
	Acres	6185	125			230							6540
1982	#	22	1				1						24
	Acres	490	3				0						493
1983	#	24	2										26
	Acres	1	0										1
1984	#	71			1	4	2	10	5				93
	Acres	1457			0	3	0	38	0				1498
1985	#	14				1		2					17
	Acres	202				80		5185					5467
1986	#	26			1			2	1	2			32
	Acres	4176			0			1	30	1000			5207
1987	#	65			1	1		6		9	3	2	87
	Acres	15,023			0	2		321		231	580	525	16,682
1988	#	9				2	1	4		1		2	19
	Acres	520				60,748	3,000	50,002		0		0	114,270
1989*													
1990	#	14						1		3			18
	Acres	170						0		470			640
1991	#	26						7					32
	Acres	6,295						942					7,237
Totals	#	340	5	1	5	10	4	32	6	15	3	4	424
	Acres	67,162	128	542	0	61,063	3,000	56,489	30	1701	580	525	191,220

* No areas reapproved for 1989

Appendix B: Master List of SBW Fires Used for Emissions Estimates

Source: Fire Effects Research Work Unit

SBW Fires - Master List

	FOR	FOR2	Year	Name	SO Num	Acres	Location	wld/pres	Topographic Maps
1	BIT	-	79	Bearfoot	41	4,600	30N15E31	p	MT George, Mt Paloma
2	BIT	-	79	Peach	64	10,400	29N15E06	p	MtGeorge,MtPaloma,TinCupLk,BurntStripMt,Watchtower
3	BIT	-	79	Saddle Gulch	123	40	28N15E08	p	Burnt Strip Mt, Watchtower Pk
4	BIT	-	81	Crooked Cr	131	330	29N14E06	w cf	Gardiner Pk, Spot Mt
5	BIT	-	81	Fire Cr	140	19	28N14E06	w cl	Spot Mt
6	BIT	-	82	Eagle Creek	17	20	29N13E04	-	Gardiner Pk
7	BIT	-	82	Little Crk	47	20	29N14E28	-	Spot Mt
8	BIT	-	82	Prince Ridge	42	30	06N22W11	w cn	Printz Ridge
9	BIT	-	82	Trail Fire	41	350	30N14E35	-	Mt George
10	BIT	-	84	Test Cr.	32	1,175	28N14E33	p	Beaver Jack Mt, Burnt Strip Mtn
11	BIT	-	84	Waldo Bar	91	20	30N14E30	p	Gardiner Pk
12	BIT	-	85	Boulder	103	30	01N22W05-32	w cl	Boulder Pk
13	BIT	-	85	Canyon Cr	53	400	29N16E08	w cf	Mt Paloma, Tin Cup Lk, Watchtower Pk, Mt Jerusalem
14	BIT	-	85	Lookout	143	200	30N14E34	p	Mt George
15	BIT	-	85	Prince Ridge	57	1,800	06N22W12	w cn	Printz Ridge
16	BIT	-	85	White Cap	118	20	29N16E06	w cf	Mt Paloma
17	BIT	-	86	Cayuse Cr	111	50	28N15E21	w cf	Nez Perce Pk
18	BIT	-	86	Fire Cr #1	129	307	29N13E34	w cf	Spot Mtn
19	BIT	-	86	North Trapper	49	100	02N22W10	p	Trapper Pk
20	BIT	-	86	Pyramid	103	281	28N13E15	w cf	Spot Mt
21	BIT	-	86	Selway River	107	409	29N14E31	w cf	Spot Mt
22	BIT	-	86	White Cap	131	435	31N16E34	w cf	Tin Cup Lk
23	BIT	-	87	Bad Luck Cr	91	10	4552 11444	p	Mt George
24	BIT	-	87	Crooked Creek	94	800	4551 11445	p	Spot Mt, Burnt Strip Mtn
25	BIT	-	87	Fox #2	106	10	4554 11436	p	Mt Paloma
26	BIT	-	87	Gabe Creek	78	100	4544 11440	p	Beaver Jack Mt
27	BIT	-	87	Gabe Creek #2	81	15	28N14E25	p	Beaver Jacl Mt
28	BIT	-	87	Granite Creek	108	900	4556 11432	p	Mt Paloma
29	BIT	-	87	Little Creek	93	800	4550 11446	p	Spot Mt, Burnt Strip Mt
30	BIT	-	87	Snake Creek	92	550	4552 11441	p	Mt George, Burnt Strip Mt
31	BIT	-	87	Triple Lakes	99	1,200	4556 11426	p	Tin Cup Lk
32	BIT	-	87	Vance Mountain	105	780	4554 11427	p	Tin Cup Lk
33	BIT	-	88	Blodgett/Footst	127	1,202	4615 11426	w cf	Blodgett Mt, Tenmile Lk
34	BIT	-	88	Cooper Lake	125	20	29N16E18	w cl	Watchtower Pk
35	BIT	-	88	Ladder Camp	131	6,000	4540 11460	-	Sabe Mt
36	BIT	-	88	Little Rock Cr	124	225	4N22W35	w cl	Como Peaks, Darby
37	BIT	-	88	Raven Creek	12	10	4546 11446	p	Spot Mt
38	BIT	-	88	Rock Cr	42	1,319	4N22W32	w cl	Como Peaks
39	BIT	-	88	Sawtooth/Footst	128	1,600	4613 11427	w cn	Tenmile Lk
40	BIT	-	88	So. Lost Horse	98	6,257	4N22W20	w cn	El Captain, Como Peaks
41	BIT	-	88	Totem Pk	108	3,050	7N22W17	w cn	Blodgett Mt, Printz Ridge, Hamilton North
42	BIT	-	88	Triple Lake	126	160	30N16E11	w cl	Tin Cup Lk
43	BIT	-	88	Wapiti	21	30	30N14E27	w cf	Mt George
44	BIT	-	88	Watchtower #2	117	20	1N23W18	w cl	Mt Jerusalem
45	BIT	-	89	Lookout Cr	185	12	30N14E11	w cl	Mt George
46	CLR	-	79	Beaver Ridge	171	89	37N16E14	w cl	Ranger Pk
47	CLR	-	79	Upper Dead Elk	64	200	35N15E11	p	Jeanette Mt
48	CLR	-	81	Blodgett	35	1,946	34N16E10	p	Jeanette Mt, Blodgett Mt
49	CLR	-	81	Cedar Creek	32	255	34N14E28	p	Cedar Ridge
50	CLR	-	81	Frog Peak	70	137	35N16E28	p	Blodgett Mt
51	CLR	-	81	Hidden Lookout	37	125	35N16E22	p	Blodgett Mt
52	CLR	-	81	Jeanette	60	15	34N15E09	w cl	Jeanette Mt
53	CLR	-	81	Tadpole Lake	59	1,368	35N16E29	p	Jeanette Mt, Blodgett
54	CLR	-	84	Cooperation	47	13	36N13E35	w	Tom Beal Pk
55	CLR	-	85	Big Flat Creek	68	1,460	35N16E14	w cn	White Sand Lk, Blodgett
56	CLR	-	85	Diablo Mountain	57	25	34N15E17	w cf	Jeanette Mt
57	CLR	-	85	Freezeout	67	260	35N12E10	w cl	Bear Mt, McConnel Mt
58	CLR	-	85	Mistake	47	40	35N15E15	w cn	Jeanette Mt

SBW Fires - Master List

	FOR	FOR2	Year	Name	SO Num	Acres	Location	wld/pres	Topographic Maps
59	CLR	-	85	White Sand	44	40	36N16E32	w cl	Savage Ridge, White Sand Lk
60	CLR	-	87	Dan Creek	104	335	4626 11431	w cf	Savage Ridge
61	CLR	-	88	Jeanette Cr	86	406	4617 11435	w cf/cl	Jeanette Mt
62	CLR	-	89	Hidden Lake	93	10	4622 11431	w cl	Jeanette Mt
63	CLR	-	89	Kidney lake	90	20	35N14E32	w cl	Cedar Ridge
64	CLR	-	90	Hidden Lake	116	5	35N15E34	p	Jeanette Mt
65	CLR	-	90	Maud Cr	71	65	36N16E05	p	White Sand Lk
66	CLR	-	90	Wind Lakes	90	95	35N14E07	p	Tom Beal Pk
67	NEZ	-	79	Dead Elk III	285	22	34N16E19	w cl	Jeanette Mt
68	NEZ	-	79	Elk Ridge	264	15	31N14E9	w cl	Twin Butte
69	NEZ	-	79	Independence	24	16,300	31N14E8	p none	Moose Ridge, Dog Cr, Twin Butte
70	NEZ	-	79	Running Crk	231	16	29N13E6	w supp	Wylies Pk
71	NEZ	-	79	Wahoo	289	15	33N15E33	p	Saddle Mt
72	NEZ	-	81	Battle Ridge	127	20	33N15E07	w cl	Wahoo Pk
73	NEZ	CLR	81	Boundary	141	300	34N15E24	w no sup	Jeanette Mt
74	NEZ	-	81	Cox Creek III	138	20	34N15E32	w cf	Saddle Mt
75	NEZ	-	81	Cox Creek IV	147	20	34N15E32	p	Saddle Mt
76	NEZ	-	81	Cox Saddle	124	1,000	33N15E04	w no sup	Jeanette Mt, Saddle Mt
77	NEZ	-	81	Divide II	130	1,270	33N16E28	w cf	Tenmile Lk
78	NEZ	-	81	Goat Lake	128	25	34N15E30	w cf	Cedar Ridge
79	NEZ	-	81	Maple	36	95	33N13E11	p	Freeman Pk
80	NEZ	-	81	Meeker Ridge	61	1,590	32N12E18	p	Big Rock Mt. Mink Pk, Moose Ridge
81	NEZ	-	81	Moose Lake	119	525	33N16E8	w no sup	Tenmile Lk
82	NEZ	-	81	Rock Point	135	25	32N15E10	w cf	Saddle Mt
83	NEZ	-	81	Spruce Lake	132	80	32N16E19	w cf	Hunter Pk
84	NEZ	-	81	Square Rock	92	20	31N12E31	w cl	Running Lk, Wylies Pk
85	NEZ	-	81	Squaw	59	645	32N14E15	p	Twin Butte
86	NEZ	-	81	Squaw II	121	875	32N15E6	w supp	Wahoo Pk
87	NEZ	-	81	Wahoo	118	870	32N15E19	w supp	Twin Butte
88	NEZ	-	81	Wahoo Pk	122	12	33N14E25	w no sup	Wahoo Pk
89	NEZ	-	82	Elevator	66	80	30N13E3	p	Gardiner Pk
90	NEZ	-	83	Cascade	60	640	32N10E25	p/w conf	Fog Mt
91	NEZ	-	84	Bear Wallow	163	11	32N11E10	p	Big Rock Mt
92	NEZ	-	84	Double Creek	124	65	33N13E9	p	Freeman Pk
93	NEZ	-	84	Footstool	157	15	34N15E28	p	Jeanette Mt
94	NEZ	-	84	Gardiner Trail	34	48	31N13E35	p	Gardiner Pk
95	NEZ	-	84	Legend	167	20	33N10E35	p	Fenn Mt
96	NEZ	-	84	Maple Lk Ridge	131	15	34N14E31	p	Freeman Pk
97	NEZ	-	84	Paradise	168	35	31N15E03	w cf	Hunter Pk
98	NEZ	-	84	Ranches	128	275	33N13E30?	p	Shissler Pk, Freeman Pk
99	NEZ	-	84	Trout Peak	127	12	33N13E32	p	Freeman Pk
100	NEZ	-	85	Diamond I	112	295	32N15E25	w cf	Hunter Pk
101	NEZ	-	85	Elk Creek II	113	20	31N13E30	w supp	Wylies Pk
102	NEZ	-	85	Fry Pan	28	95	31N14E32	w cf	Mt George
103	NEZ	CLR	85	Little Dead Elk	106	3,265	34N15E24	w cf	Jeanette Mt, Blodgett Mt, Tenmile Lk
104	NEZ	-	85	Rock Point	131	32	32N15E16	w cf	Hunter Pk
105	NEZ	-	85	Shasta	13	1,100	33N12E03	w?	Shissler Pk
106	NEZ	-	85	Wahoo II	133	185	32N15E18	w cf	Saddle Mt, Twin Butte, Hunter Pk
107	NEZ	-	85	Wahoo Ridge	99	430	33N15E35	w cf	Saddle Mt
108	NEZ	-	86	Bear Wallow	46	1,525	4607 11504	w cf	Mink Pk
109	NEZ	-	86	Dog I	13	4,020	4605 11452	p	Shissler Pk, Moose Ridge, Dog Cr
110	NEZ	-	86	Elk Creek	49	470	4559 11453	w cf	Wylies Pk
111	NEZ	-	86	Goat Heaven	136	30	4614 11438	w cf	Wahoo Pk
112	NEZ	-	86	Halfway	130	50	4609 11458	w cf	Shissler Pk
113	NEZ	-	86	Highline	12	40	4602 11507	p	Mink Pk
114	NEZ	-	86	Lone Pine	50	940	4605 11501	w cf	Mink Pk
115	NEZ	-	86	Mink	47	2,480	4607 11505	w cf	Mink Pk
116	NEZ	-	86	Moose	134	80	4615 11430	w cf	Tenmile Lk

SBW Fires - Master List

	FOR	FOR2	Year	Name	SO Num	Acres	Location	wld/pres	Topographic Maps
117	NEZ	"	86	North Peak	51	110	4613 11502	w cf	Big Rock Mt
118	NEZ	"	86	Puzzle	48	2,050	4607 11458	w ct?	Moose Ridge
119	NEZ	"	87	Ballinger	182	15	4606 15509		Fog Mt
120	NEZ	"	87	Bear	52	7,500	"	p	Dog Cr, Twin Butte, Gardiner Pk, Mt George
121	NEZ	"	87	Double II	135	115	4612 11449	p	Freeman Pk
122	NEZ	"	87	Eben	180	625	"	p	Twin Butte
123	NEZ	"	87	Fox	156	60	4602 11456	p	Moose Ridge
124	NEZ	"	87	Fry Pan	134	174	4558 11443	p	Mt George
125	NEZ	"	87	Granite	77	36	4608 11435	p	Saddle Mt
126	NEZ	"	87	Halfway	47	695	4608 11459	p	Shissler Pk, Mink Pk, Moose Ridge
127	NEZ	"	87	Meeker Ridge	57	50	4610 11500	p	Shissler Pk
128	NEZ	"	87	Monument	62	550	4510 11445	p	Freeman Pk, Wahoo Pk — Should be 46 10
129	NEZ	"	87	Papoose	59	21	4607 11447	p	Freeman Pk, Dog Cr
130	NEZ	"	87	Pinchot Pt	79	15	467 1155	p	Mink Pk
131	NEZ	"	87	Ranches	181	952	4610 11452	w	Shissler Pk, Freeman Pk
132	NEZ		88	Footstool	35	13,900	4616 11436	w cf	CedarR,JeanetteM,BlodgettM,WahooP,SaddleM,TenmileL
133	NEZ	"	88	Fox	141	10	4618 11447	w cl	Hungry Rock
134	NEZ	"	88	Freeman Trail	27	23,220	4607 11449	w cf	Freeman Pk, Wahoo Pk, Dog Cr, Twin Butte
135	NEZ	BIT	88	Gardiner	135	1,270	4559 11445	w cf	Gardiner Pk, Mt George
136	NEZ	BIT	88	Upper Bear	42	5,180	4607	w cf	Saddle Mt, Tenmile Lk, Hunter Pk, El Captain
137	NEZ	"	89	Wahoo	323	25	4610 11440	w ctn	Wahoo Pk

Appendix C: Estimated SBW Emissions for Low, Average, and High Combustion Efficiencies

Source: Fire Effects Research Work Unit

Estimated emissions (thousands of pounds) by year and burning period based on LOW combustion efficiency

BITTERROOT

FR	YR	BP	TOTAL P	2.5 m	CO	MH4
3	79	7	12.	9.	102.	5.
3	79	8	107.	71.	877.	42.
3	79	9	256.	170.	2103.	99.
3	79	10	1862.	1240.	15344.	722.
3	79	11	2169.	1444.	17825.	840.
3	79	13	577.	384.	4753.	224.
3	79	14	149.	99.	1243.	58.
3	79	15	1472.	981.	12116.	570.
3	79	17	55.	36.	455.	21.
3	81	12	206.	138.	1700.	80.
3	81	14	4.	3.	36.	1.
3	82	9	9.	6.	75.	4.
3	82	12	203.	135.	1668.	79.
3	82	15	15.	10.	124.	6.
3	84	10	5.	3.	40.	1.
3	84	11	118.	79.	974.	46.
3	84	12	458.	304.	3745.	177.
3	84	13	99.	66.	813.	38.
3	85	7	5.	4.	45.	2.
3	85	8	18.	12.	152.	7.
3	85	9	568.	379.	4723.	221.
3	85	11	181.	121.	1522.	72.
3	85	13	171.	114.	1411.	67.
3	86	11	239.	159.	1963.	93.
3	86	12	781.	520.	6464.	303.
3	86	13	182.	122.	1516.	71.
3	87	12	109.	73.	905.	43.
3	87	13	42.	30.	352.	16.
3	87	14	1988.	1326.	16412.	772.
3	87	15	719.	479.	5954.	280.
3	87	16	361.	239.	2979.	142.
3	88	7	16.	10.	130.	6.
3	88	9	699.	464.	5691.	269.
3	88	11	296.	198.	2459.	115.
3	88	12	2392.	1595.	19764.	929.
3	88	13	6044.	4023.	49668.	2338.
3	89	10	9.	6.	75.	4.
	TOTAL		22596.	15052.	186178.	8763.

CLEARWATER

FR	YR	BP	TOTAL P	2.5 m	CO	MH4
5	79	10	190.	127.	1583.	74.
5	79	14	37.	25.	311.	15.
5	81	11	80.	54.	663.	31.
5	81	12	833.	554.	6816.	322.
5	81	14	1213.	804.	9824.	464.
5	84	12	9.	6.	78.	4.
5	85	8	123.	83.	1027.	47.
5	85	9	925.	614.	7573.	356.
5	87	18	65.	43.	536.	25.
5	88	13	346.	228.	2763.	131.
5	89	10	20.	12.	158.	6.
5	90	14	26.	17.	225.	10.
5	90	15	40.	27.	333.	15.
5	90	16	24.	16.	203.	10.
	TOTAL		3931.	2610.	32093.	1510.

NEZ PERCE

FR	YR	BP	TOTAL P	2.5 m	CO	MH4
17	79	7	64.	42.	520.	25.
17	79	8	201.	133.	1639.	78.
17	79	9	743.	495.	6101.	287.
17	79	10	5236.	3488.	43064.	2027.
17	79	11	1747.	1161.	14270.	672.
17	79	12	161.	108.	1340.	63.
17	79	13	25.	17.	213.	10.
17	79	15	11.	7.	91.	5.
17	81	9	87.	57.	717.	34.
17	81	10	258.	171.	2134.	99.
17	81	11	321.	214.	2655.	125.
17	81	12	3799.	2524.	31086.	1464.
17	81	13	705.	469.	5826.	274.
17	81	14	252.	168.	2113.	99.
17	82	12	43.	29.	350.	16.
17	83	12	170.	113.	1411.	67.
17	84	10	16.	11.	138.	6.
17	84	11	10.	8.	88.	4.
17	84	12	250.	167.	2082.	96.
17	84	13	21.	14.	179.	9.
17	85	7	3.	2.	26.	1.
17	85	8	531.	353.	4367.	206.
17	85	9	2788.	1856.	22942.	1079.
17	85	10	7.	5.	62.	3.
17	86	7	24.	15.	199.	10.
17	86	9	60.	40.	491.	23.
17	86	10	2032.	1352.	16667.	785.
17	86	11	2970.	1981.	24517.	1154.
17	86	12	1887.	1259.	15668.	735.
17	87	8	95.	64.	789.	37.
17	87	10	788.	526.	6508.	306.
17	87	11	72.	48.	602.	28.
17	87	13	34.	23.	278.	13.
17	87	14	2328.	1551.	19133.	901.
17	87	15	1679.	1118.	13806.	649.
17	87	16	1730.	1150.	14173.	667.
17	87	17	848.	561.	6900.	325.
17	87	18	976.	650.	8018.	377.
17	87	19	16.	11.	129.	7.
17	88	12	3746.	2489.	30609.	1442.
17	88	13	32008.	21219.	259411.	12255.
17	88	14	1193.	792.	9697.	458.
17	89	15	12.	8.	100.	5.
	TOTAL		69947.	46469.	571109.	26926.

WILDERNESS TOTALS

YR	BP	TOTAL P	2.5 m	CO	MH4
79	7	76.	51.	622.	30.
79	8	308.	204.	2516.	120.
79	9	999.	665.	8204.	386.
79	10	7288.	4855.	59991.	2823.
79	11	3916.	2605.	32095.	1512.
79	12	161.	108.	1340.	63.
79	13	602.	401.	4966.	234.
79	14	186.	124.	1554.	73.
79	15	1483.	988.	12207.	575.
79	17	55.	36.	455.	21.
81	9	87.	57.	717.	34.
81	10	258.	171.	2134.	99.
81	11	401.	268.	3318.	156.
81	12	4838.	3216.	39602.	1866.
81	13	705.	469.	5826.	274.
81	14	1469.	975.	11973.	564.
82	9	9.	6.	75.	4.
82	12	246.	164.	2018.	95.
82	15	15.	10.	124.	6.
83	12	170.	113.	1411.	67.
84	10	21.	14.	178.	7.
84	11	128.	87.	1062.	50.
84	12	717.	477.	5905.	277.
84	13	120.	80.	992.	47.
85	7	8.	6.	71.	3.
85	8	672.	448.	5546.	260.
85	9	4281.	2849.	35238.	1656.
85	10	7.	5.	62.	3.
85	11	181.	121.	1522.	72.
85	13	171.	114.	1411.	67.
86	7	24.	15.	199.	10.
86	9	60.	40.	491.	23.
86	10	2032.	1352.	16667.	785.
86	11	3209.	2140.	26480.	1247.
86	12	2668.	1779.	22132.	1038.
86	13	182.	122.	1516.	71.
87	8	95.	64.	789.	37.
87	10	788.	526.	6508.	306.
87	11	72.	48.	602.	28.
87	12	109.	73.	905.	43.
87	13	76.	53.	630.	29.
87	14	4316.	2877.	35545.	1673.
87	15	2398.	1597.	19760.	929.
87	16	2091.	1389.	17152.	809.
87	17	848.	561.	6900.	325.
87	18	1041.	693.	8554.	402.
87	19	16.	11.	129.	7.
88	7	16.	10.	130.	6.
88	9	699.	464.	5691.	269.
88	11	296.	198.	2459.	115.
88	12	6138.	4084.	50373.	2371.
88	13	38398.	25470.	311842.	14724.
88	14	1193.	792.	9697.	458.
89	10	29.	18.	233.	10.
89	15	12.	8.	100.	5.
90	14	26.	17.	225.	10.
90	15	40.	27.	333.	15.
90	16	24.	16.	203.	10.
TOTAL		96474.	64131.	789380.	37199.

Estimated emissions (thousands of pounds) by year and burning period based on AVERAGE combustion efficiency

BITTERROOT

FR	YR	BP	TOTAL P	2.5 m	CO	MH4
3	79	7	10.	6.	78.	3.
3	79	8	87.	57.	662.	31.
3	79	9	209.	136.	1588.	76.
3	79	10	1522.	991.	11612.	556.
3	79	11	1773.	1152.	13467.	646.
3	79	13	472.	307.	3593.	172.
3	79	14	123.	81.	951.	46.
3	79	15	1205.	785.	9194.	441.
3	79	17	45.	29.	347.	17.
3	81	12	168.	109.	1286.	62.
3	81	14	4.	3.	27.	1.
3	82	9	8.	5.	57.	2.
3	82	12	166.	108.	1261.	61.
3	82	15	13.	7.	95.	5.
3	84	10	4.	3.	30.	1.
3	84	11	97.	63.	738.	36.
3	84	12	374.	242.	2819.	135.
3	84	13	81.	52.	612.	29.
3	85	7	5.	2.	35.	1.
3	85	8	15.	10.	116.	6.
3	85	9	466.	304.	3594.	171.
3	85	11	149.	98.	1163.	55.
3	85	13	140.	92.	1069.	51.
3	86	11	194.	128.	1484.	72.
3	86	12	639.	416.	4908.	235.
3	86	13	149.	98.	1156.	55.
3	87	12	89.	58.	687.	33.
3	87	13	34.	22.	265.	12.
3	87	14	1638.	1065.	12505.	599.
3	87	15	592.	385.	4545.	218.
3	87	16	296.	194.	2269.	109.
3	88	7	13.	8.	98.	4.
3	88	9	570.	369.	4274.	205.
3	88	11	243.	158.	1871.	90.
3	88	12	1956.	1275.	14983.	717.
3	88	13	4936.	3208.	37527.	1802.
3	89	10	8.	5.	57.	2.
	TOTAL		18493.	12031.	141023.	6757.

CLEARWATER

FR	YR	BP	TOTAL P	2.5 m	CO	MH4
5	79	10	156.	102.	1207.	57.
5	79	14	31.	20.	236.	11.
5	81	11	66.	42.	503.	24.
5	81	12	679.	441.	5135.	248.
5	81	14	988.	637.	7351.	354.
5	84	12	8.	5.	59.	2.
5	85	8	101.	67.	781.	38.
5	85	9	754.	490.	5710.	274.
5	87	18	53.	34.	404.	19.
5	88	13	280.	180.	2048.	99.
5	89	10	16.	10.	119.	6.
5	90	14	23.	15.	172.	8.
5	90	15	33.	21.	254.	12.
5	90	16	20.	13.	154.	7.
	TOTAL		3208.	2077.	24133.	1159.

NEZ PERCE

FR	YR	BP	TOTAL P	2.5 m	CO	MH4
17	79	7	52.	34.	392.	19.
17	79	8	163.	107.	1235.	60.
17	79	9	607.	395.	4605.	221.
17	79	10	4280.	2782.	32541.	1561.
17	79	11	1425.	924.	10736.	516.
17	79	12	132.	86.	1021.	49.
17	79	13	21.	13.	163.	8.
17	79	15	9.	6.	70.	3.
17	81	9	71.	47.	546.	27.
17	81	10	211.	138.	1621.	78.
17	81	11	262.	171.	2018.	97.
17	81	12	3098.	2013.	23416.	1125.
17	81	13	577.	377.	4419.	211.
17	81	14	208.	136.	1619.	77.
17	82	12	35.	23.	263.	13.
17	83	12	139.	91.	1072.	51.
17	84	10	13.	9.	104.	5.
17	84	11	9.	6.	67.	4.
17	84	12	203.	134.	1585.	75.
17	84	13	18.	11.	136.	6.
17	85	7	3.	1.	20.	1.
17	85	8	435.	282.	3299.	158.
17	85	9	2279.	1482.	17342.	831.
17	85	10	7.	4.	47.	2.
17	86	7	19.	13.	151.	7.
17	86	9	48.	32.	372.	17.
17	86	10	1661.	1078.	12569.	603.
17	86	11	2427.	1584.	18570.	888.
17	86	12	1546.	1008.	11917.	571.
17	87	8	78.	50.	597.	29.
17	87	10	646.	420.	4929.	237.
17	87	11	60.	39.	457.	22.
17	87	13	28.	18.	210.	10.
17	87	14	1919.	1248.	14582.	699.
17	87	15	1385.	901.	10533.	505.
17	87	16	1421.	922.	10750.	516.
17	87	17	694.	451.	5207.	251.
17	87	18	803.	522.	6123.	293.
17	87	19	13.	8.	97.	4.
17	88	12	3056.	1981.	23035.	1108.
17	88	13	26059.	16838.	194190.	9365.
17	88	14	974.	630.	7282.	352.
17	89	15	10.	6.	75.	4.
	TOTAL		57104.	37021.	429983.	20679.

WILDERNESS TOTALS

YR	BP	TOTAL P	2.5 m	CO	MH4
79	7	62.	40.	470.	22.
79	8	250.	164.	1897.	91.
79	9	816.	531.	6193.	297.
79	10	5958.	3875.	45360.	2174.
79	11	3198.	2076.	24203.	1162.
79	12	132.	86.	1021.	49.
79	13	493.	320.	3756.	180.
79	14	154.	101.	1187.	57.
79	15	1214.	791.	9264.	444.
79	17	45.	29.	347.	17.
81	9	71.	47.	546.	27.
81	10	211.	138.	1621.	78.
81	11	328.	213.	2521.	121.
81	12	3945.	2563.	29837.	1435.
81	13	577.	377.	4419.	211.
81	14	1200.	776.	8997.	432.
82	9	8.	5.	57.	2.
82	12	201.	131.	1524.	74.
82	15	13.	7.	95.	5.
83	12	139.	91.	1072.	51.
84	10	17.	12.	134.	6.
84	11	106.	69.	805.	40.
84	12	585.	381.	4463.	212.
84	13	99.	63.	748.	35.
85	7	8.	3.	55.	2.
85	8	551.	359.	4196.	202.
85	9	3499.	2276.	26646.	1276.
85	10	7.	4.	47.	2.
85	11	149.	98.	1163.	55.
85	13	140.	92.	1069.	51.
86	7	19.	13.	151.	7.
86	9	48.	32.	372.	17.
86	10	1661.	1078.	12569.	603.
86	11	2621.	1712.	20054.	960.
86	12	2185.	1424.	16825.	806.
86	13	149.	98.	1156.	55.
87	8	78.	50.	597.	29.
87	10	646.	420.	4929.	237.
87	11	60.	39.	457.	22.
87	12	89.	58.	687.	33.
87	13	62.	40.	475.	22.
87	14	3557.	2313.	27087.	1298.
87	15	1977.	1286.	15078.	723.
87	16	1717.	1116.	13019.	625.
87	17	694.	451.	5207.	251.
87	18	856.	556.	6527.	312.
87	19	13.	8.	97.	4.
88	7	13.	8.	98.	4.
88	9	570.	369.	4274.	205.
88	11	243.	158.	1871.	90.
88	12	5012.	3256.	38018.	1825.
88	13	31275.	20226.	233765.	11266.
88	14	974.	630.	7282.	352.
89	10	24.	15.	176.	8.
89	15	10.	6.	75.	4.
90	14	23.	15.	172.	8.
90	15	33.	21.	254.	12.
90	16	20.	13.	154.	7.
TOTAL		78805.	51129.	595139.	28595.

Estimated emissions (thousands of pounds) by year and burning period based on HIGH combustion efficiency

BITTERROOT

FR	YR	BP	TOTAL P	2.5 m	CO	MH4
3	79	7	9.	4.	55.	2.
3	79	8	67.	42.	448.	22.
3	79	9	162.	101.	1076.	53.
3	79	10	1182.	741.	7906.	391.
3	79	11	1375.	860.	9136.	453.
3	79	13	367.	230.	2440.	121.
3	79	14	95.	59.	655.	32.
3	79	15	934.	585.	6234.	310.
3	79	17	35.	22.	238.	11.
3	81	12	132.	82.	873.	44.
3	81	14	3.	1.	19.	1.
3	82	9	6.	4.	39.	2.
3	82	12	128.	81.	856.	43.
3	82	15	10.	6.	66.	3.
3	84	10	3.	2.	21.	1.
3	84	11	75.	47.	504.	25.
3	84	12	290.	181.	1897.	95.
3	84	13	63.	39.	412.	21.
3	85	7	4.	2.	25.	1.
3	85	8	12.	7.	80.	4.
3	85	9	363.	229.	2472.	121.
3	85	11	116.	74.	809.	40.
3	85	13	109.	68.	728.	36.
3	86	11	152.	95.	1007.	51.
3	86	12	498.	313.	3365.	164.
3	86	13	117.	74.	799.	39.
3	87	12	69.	44.	469.	23.
3	87	13	28.	17.	181.	9.
3	87	14	1265.	793.	8469.	419.
3	87	15	459.	288.	3093.	153.
3	87	16	231.	143.	1547.	76.
3	88	7	10.	8.	68.	2.
3	88	9	440.	274.	2864.	143.
3	88	11	189.	118.	1286.	64.
3	88	12	1522.	955.	10235.	506.
3	88	13	3830.	2396.	25463.	1262.
3	89	10	6.	4.	40.	2.
	TOTAL		14356.	8989.	95875.	4745.

CLEARWATER

FR	YR	BP	TOTAL P	2.5 m	CO	MH4
5	79	10	122.	77.	835.	41.
5	79	14	24.	16.	163.	8.
5	81	11	51.	32.	344.	17.
5	81	12	526.	328.	3463.	170.
5	81	14	761.	472.	4887.	245.
5	84	12	6.	4.	41.	2.
5	85	8	79.	50.	535.	26.
5	85	9	585.	365.	3859.	192.
5	87	18	41.	26.	274.	14.
5	88	13	215.	132.	1334.	68.
5	89	10	12.	8.	82.	4.
5	90	14	17.	11.	120.	5.
5	90	15	25.	16.	174.	9.
5	90	16	16.	10.	107.	6.
	TOTAL		2480.	1547.	16218.	807.

NEZ PERCE

FR	YR	BP	TOTAL P	2.5 m	CO	MH4
17	79	7	40.	25.	266.	13.
17	79	8	126.	79.	834.	41.
17	79	9	471.	294.	3120.	155.
17	79	10	3322.	2077.	22088.	1095.
17	79	11	1103.	686.	7221.	360.
17	79	12	103.	65.	703.	35.
17	79	13	16.	10.	113.	6.
17	79	15	7.	5.	48.	2.
17	81	9	56.	35.	375.	19.
17	81	10	164.	103.	1113.	54.
17	81	11	204.	129.	1386.	68.
17	81	12	2402.	1497.	15791.	783.
17	81	13	449.	281.	3021.	149.
17	81	14	162.	102.	1124.	55.
17	82	12	27.	17.	177.	9.
17	83	12	108.	68.	734.	36.
17	84	10	10.	6.	72.	3.
17	84	11	6.	5.	46.	2.
17	84	12	158.	101.	1092.	52.
17	84	13	14.	8.	94.	5.
17	85	7	2.	1.	14.	1.
17	85	8	337.	210.	2238.	110.
17	85	9	1768.	1106.	11778.	582.
17	85	10	5.	3.	32.	1.
17	86	7	15.	10.	105.	6.
17	86	9	38.	23.	253.	13.
17	86	10	1286.	804.	8496.	423.
17	86	11	1888.	1184.	12666.	627.
17	86	12	1203.	759.	8196.	405.
17	87	8	61.	38.	407.	19.
17	87	10	503.	314.	3363.	166.
17	87	11	47.	29.	313.	16.
17	87	13	21.	14.	143.	7.
17	87	14	1475.	922.	9798.	487.
17	87	15	1065.	666.	7079.	351.
17	87	16	1094.	682.	7213.	358.
17	87	17	534.	332.	3460.	172.
17	87	18	619.	386.	4119.	204.
17	87	19	10.	6.	67.	3.
17	88	12	2366.	1474.	15501.	772.
17	88	13	20113.	12458.	129248.	6475.
17	88	14	753.	466.	4849.	243.
17	89	15	8.	5.	52.	2.
	TOTAL		44159.	27485.	288808.	14385.

WILDERNESS TOTALS

YR	BP	TOTAL P	2.5 m	CO	MH4
79	7	49.	29.	321.	15.
79	8	193.	121.	1282.	63.
79	9	633.	395.	4196.	208.
79	10	4626.	2895.	30829.	1527.
79	11	2478.	1546.	16357.	813.
79	12	103.	65.	703.	35.
79	13	383.	240.	2553.	127.
79	14	119.	75.	818.	40.
79	15	941.	590.	6282.	312.
79	17	35.	22.	238.	11.
81	9	56.	35.	375.	19.
81	10	164.	103.	1113.	54.
81	11	255.	161.	1730.	85.
81	12	3060.	1907.	20127.	997.
81	13	449.	281.	3021.	149.
81	14	926.	575.	6030.	301.
82	9	6.	4.	39.	2.
82	12	155.	98.	1033.	52.
82	15	10.	6.	66.	3.
83	12	108.	68.	734.	36.
84	10	13.	8.	93.	4.
84	11	81.	52.	550.	27.
84	12	454.	286.	3030.	149.
84	13	77.	47.	506.	26.
85	7	6.	3.	39.	2.
85	8	428.	267.	2853.	140.
85	9	2716.	1700.	18109.	895.
85	10	5.	3.	32.	1.
85	11	116.	74.	809.	40.
85	13	109.	68.	728.	36.
86	7	15.	10.	105.	6.
86	9	38.	23.	253.	13.
86	10	1286.	804.	8496.	423.
86	11	2040.	1279.	13673.	678.
86	12	1701.	1072.	11561.	569.
86	13	117.	74.	799.	39.
87	8	61.	38.	407.	19.
87	10	503.	314.	3363.	166.
87	11	47.	29.	313.	16.
87	12	69.	44.	469.	23.
87	13	49.	31.	324.	16.
87	14	2740.	1715.	18267.	906.
87	15	1524.	954.	10172.	504.
87	16	1325.	825.	8760.	434.
87	17	534.	332.	3460.	172.
87	18	660.	412.	4393.	218.
87	19	10.	6.	67.	3.
88	7	10.	8.	68.	2.
88	9	440.	274.	2864.	143.
88	11	189.	118.	1286.	64.
88	12	3888.	2429.	25736.	1278.
88	13	24158.	14986.	156045.	7805.
88	14	753.	466.	4849.	243.
89	10	18.	12.	122.	6.
89	15	8.	5.	52.	2.
90	14	17.	11.	120.	5.
90	15	25.	16.	174.	9.
90	16	16.	10.	107.	6.
TOTAL		60995.	38021.	400901.	19937.

Appendix D: VALBOX Output from Saddle Gulch Fire Simulation

VENTILATED VALLEY BOX MODEL

The box, simulation time and meteorology descriptions
used to make this run are from SADDLE.DAT .

The emission inventory is from SADDLE.EMS .

Box Descriptions from SADDLE.DAT
1. Fire/Site Name .....
SADDLE GULCH

2. Number of boxes ..... 1 box(es)
3. Volume of each box (millions of cubic feet)
Box 1 500000. Box
4. Initial concentration in each box (micrograms/cubic meter)
Box 1 0.0 Box
5. Flow from box (up valley) (down valley)

		1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
I	1	0								0							
n	2																
t	3																
o	4																
	5																
b	6																
o	7																
x	8																

6. Box with wind observations 1
7. Width of wind obs. box ..... 12000.0 feet
8. Daytime mixing height ..... 2500.0 feet
9. Nighttime mixing height ..... 500.0 feet

Simulation times from SADDLE.DAT
1. Begin date/time of the simulationtion (mm/dd/yyyy hh:mm)
9/15/1979 0: 0
2. End date/time of the simulation period (mm/dd/yyyy hh:mm)
9/17/1979 23: 0
3. Duration of each simulation time step 60.00 minutes

Meteorology Description from SADDLE.DAT

Time Step Number	Date/Time of Change (mm/dd/yyyy hh:mm)	Wind Direction (Valley Axis)	Wind Speed (mph)	Time Step Number	Date/Time of Change (mm/dd/yyyy hh:mm)	Wind Direction (Valley Axis)	Wind Speed (mph)
1	9/15/1979 0: 0	DOWN	2.0	2	9/15/1979 8: 0	CALM	0.0
3	9/15/1979 9: 0	UP	1.0	4	9/15/1979 12: 0	UP	3.0
5	9/15/1979 20: 0	CALM	0.0	6	9/15/1979 21: 0	DOWN	2.0
7	9/16/1979 8: 0	CALM	0.0	8	9/16/1979 9: 0	UP	2.0
9	9/16/1979 12: 0	UP	4.0	10	9/16/1979 17: 0	UP	1.0
11	9/16/1979 21: 0	DOWN	2.0	12	9/17/1979 8: 0	CALM	0.0
13	9/17/1979 9: 0	UP	2.0	14	9/17/1979 12: 0	UP	4.0
15	9/17/1979 18: 0	UP	2.0	16	9/17/1979 20: 0	CALM	0.0
17	9/17/1979 21: 0	DOWN	2.0				

Emission Inventory for TSP from SADDLE.EMS

Time Step Number	Date/Time of Change (mm/dd/yyyy hh:mm)	Emissions (g/s) for box 1
1	9/15/1979 0: 0	11.0
2	9/15/1979 13: 0	166.0
3	9/15/1979 18: 0	11.0
4	9/16/1979 13: 0	166.0
5	9/16/1979 18: 0	11.0
6	9/17/1979 13: 0	166.0
7	9/17/1979 18: 0	11.0

SADDLE GULCH

TSP concentrations for TIME STEP averaging time

Time Step Number	Date/Time (mm/dd/yyyy hh:mm)	Concentration (ug/m**3) for box 1
1	9/15/1979 0: 0	0.0
2	9/15/1979 1: 0	2.7
3	9/15/1979 2: 0	5.2
4	9/15/1979 3: 0	7.3
5	9/15/1979 4: 0	9.1
6	9/15/1979 5: 0	10.7
7	9/15/1979 6: 0	12.1
8	9/15/1979 7: 0	13.4
9	9/15/1979 8: 0	7.8
10	9/15/1979 9: 0	10.5
11	9/15/1979 10: 0	10.0
12	9/15/1979 11: 0	9.6
13	9/15/1979 12: 0	9.4
14	9/15/1979 13: 0	3.4
15	9/15/1979 14: 0	41.7
16	9/15/1979 15: 0	44.2
17	9/15/1979 16: 0	44.4
18	9/15/1979 17: 0	44.4
19	9/15/1979 18: 0	44.4
20	9/15/1979 19: 0	5.7
21	9/15/1979 20: 0	3.1
22	9/15/1979 21: 0	5.9
23	9/15/1979 22: 0	7.9
24	9/15/1979 23: 0	9.7
25	9/16/1979 0: 0	11.2
26	9/16/1979 1: 0	12.6
27	9/16/1979 2: 0	13.7
28	9/16/1979 3: 0	14.8
29	9/16/1979 4: 0	15.7
30	9/16/1979 5: 0	16.5
31	9/16/1979 6: 0	17.2
32	9/16/1979 7: 0	17.8
33	9/16/1979 8: 0	9.5
34	9/16/1979 9: 0	12.2
35	9/16/1979 10: 0	7.4
36	9/16/1979 11: 0	5.5
37	9/16/1979 12: 0	4.8
38	9/16/1979 13: 0	1.6
39	9/16/1979 14: 0	41.1
40	9/16/1979 15: 0	31.4
41	9/16/1979 16: 0	33.8
42	9/16/1979 17: 0	33.2
43	9/16/1979 18: 0	64.3
44	9/16/1979 19: 0	47.1

45	9/16/1979	20: 0	35.2
46	9/16/1979	21: 0	35.7
47	9/16/1979	22: 0	34.0
48	9/16/1979	23: 0	32.5
49	9/17/1979	0: 0	31.2
50	9/17/1979	1: 0	30.1
51	9/17/1979	2: 0	29.1
52	9/17/1979	3: 0	28.2
53	9/17/1979	4: 0	27.5
54	9/17/1979	5: 0	26.8
55	9/17/1979	6: 0	26.2
56	9/17/1979	7: 0	25.7
57	9/17/1979	8: 0	12.4
58	9/17/1979	9: 0	15.2
59	9/17/1979	10: 0	8.5
60	9/17/1979	11: 0	5.9
61	9/17/1979	12: 0	5.0
62	9/17/1979	13: 0	1.5
63	9/17/1979	14: 0	41.1
64	9/17/1979	15: 0	31.4
65	9/17/1979	16: 0	33.8
66	9/17/1979	17: 0	33.2
67	9/17/1979	18: 0	33.3
68	9/17/1979	19: 0	15.3
69	9/17/1979	20: 0	8.5
70	9/17/1979	21: 0	11.3
71	9/17/1979	22: 0	12.6

Average 19.8
Standard Deviation 14.5
The minimum concentration 0.0 occurred at time step 1 in box 1
The maximum concentration 64.3 occurred at time step 43 in box 1

SADDLE GULCH

TSP concentrations for ONE hour averaging time

Time Step Number	Date/Time (mm/dd/yyyy hh:mm)		Concentration (ug/m**3) for box 1
1	9/15/1979	0: 0	0.0
2	9/15/1979	1: 0	2.7
3	9/15/1979	2: 0	5.2
4	9/15/1979	3: 0	7.3
5	9/15/1979	4: 0	9.1
6	9/15/1979	5: 0	10.7
7	9/15/1979	6: 0	12.1
8	9/15/1979	7: 0	13.4
9	9/15/1979	8: 0	7.8
10	9/15/1979	9: 0	10.5
11	9/15/1979	10: 0	10.0
12	9/15/1979	11: 0	9.6
13	9/15/1979	12: 0	9.4
14	9/15/1979	13: 0	3.4
15	9/15/1979	14: 0	41.7
16	9/15/1979	15: 0	44.2
17	9/15/1979	16: 0	44.4
18	9/15/1979	17: 0	44.4
19	9/15/1979	18: 0	44.4
20	9/15/1979	19: 0	5.7
21	9/15/1979	20: 0	3.1
22	9/15/1979	21: 0	5.9
23	9/15/1979	22: 0	7.9

24	9/15/1979	23: 0	9.7
25	9/16/1979	0: 0	11.2
26	9/16/1979	1: 0	12.6
27	9/16/1979	2: 0	13.7
28	9/16/1979	3: 0	14.8
29	9/16/1979	4: 0	15.7
30	9/16/1979	5: 0	16.5
31	9/16/1979	6: 0	17.2
32	9/16/1979	7: 0	17.8
33	9/16/1979	8: 0	9.5
34	9/16/1979	9: 0	12.2
35	9/16/1979	10: 0	7.4
36	9/16/1979	11: 0	5.5
37	9/16/1979	12: 0	4.8
38	9/16/1979	13: 0	1.6
39	9/16/1979	14: 0	41.1
40	9/16/1979	15: 0	31.4
41	9/16/1979	16: 0	33.8
42	9/16/1979	17: 0	33.2
43	9/16/1979	18: 0	64.3
44	9/16/1979	19: 0	47.1
45	9/16/1979	20: 0	35.2
46	9/16/1979	21: 0	35.7
47	9/16/1979	22: 0	34.0
48	9/16/1979	23: 0	32.5
49	9/17/1979	0: 0	31.2
50	9/17/1979	1: 0	30.1
51	9/17/1979	2: 0	29.1
52	9/17/1979	3: 0	28.2
53	9/17/1979	4: 0	27.5
54	9/17/1979	5: 0	26.8
55	9/17/1979	6: 0	26.2
56	9/17/1979	7: 0	25.7
57	9/17/1979	8: 0	12.4
58	9/17/1979	9: 0	15.2
59	9/17/1979	10: 0	8.5
60	9/17/1979	11: 0	5.9
61	9/17/1979	12: 0	5.0
62	9/17/1979	13: 0	1.5
63	9/17/1979	14: 0	41.1
64	9/17/1979	15: 0	31.4
65	9/17/1979	16: 0	33.8
66	9/17/1979	17: 0	33.2
67	9/17/1979	18: 0	33.3
68	9/17/1979	19: 0	15.3
69	9/17/1979	20: 0	8.5
70	9/17/1979	21: 0	11.3
71	9/17/1979	22: 0	12.6

Average 19.8
Standard Deviation 14.5
The minimum concentration 0.0 occurred at time step 1 in box 1
The maximum concentration 64.3 occurred at time step 43 in box 1

SADDLE GULCH

TSP concentrations for THREE hour averaging time

Time Step Number	Date/Time (mm/dd/yyyy hh:mm)	Concentration (ug/m**3) for box 1
3	9/15/1979 2: 0	2.6
4	9/15/1979 3: 0	5.1

5	9/15/1979	4: 0	7.2
6	9/15/1979	5: 0	9.0
7	9/15/1979	6: 0	10.7
8	9/15/1979	7: 0	12.1
9	9/15/1979	8: 0	11.1
10	9/15/1979	9: 0	10.6
11	9/15/1979	10: 0	9.4
12	9/15/1979	11: 0	10.1
13	9/15/1979	12: 0	9.7
14	9/15/1979	13: 0	7.5
15	9/15/1979	14: 0	18.2
16	9/15/1979	15: 0	29.8
17	9/15/1979	16: 0	43.4
18	9/15/1979	17: 0	44.3
19	9/15/1979	18: 0	44.4
20	9/15/1979	19: 0	31.5
21	9/15/1979	20: 0	17.7
22	9/15/1979	21: 0	4.9
23	9/15/1979	22: 0	5.6
24	9/15/1979	23: 0	7.8
25	9/16/1979	0: 0	9.6
26	9/16/1979	1: 0	11.1
27	9/16/1979	2: 0	12.5
28	9/16/1979	3: 0	13.7
29	9/16/1979	4: 0	14.7
30	9/16/1979	5: 0	15.6
31	9/16/1979	6: 0	16.4
32	9/16/1979	7: 0	17.1
33	9/16/1979	8: 0	14.8
34	9/16/1979	9: 0	13.2
35	9/16/1979	10: 0	9.7
36	9/16/1979	11: 0	8.4
37	9/16/1979	12: 0	5.9
38	9/16/1979	13: 0	4.0
39	9/16/1979	14: 0	15.8
40	9/16/1979	15: 0	24.7
41	9/16/1979	16: 0	35.4
42	9/16/1979	17: 0	32.8
43	9/16/1979	18: 0	43.8
44	9/16/1979	19: 0	48.2
45	9/16/1979	20: 0	48.8
46	9/16/1979	21: 0	39.3
47	9/16/1979	22: 0	35.0
48	9/16/1979	23: 0	34.1
49	9/17/1979	0: 0	32.6
50	9/17/1979	1: 0	31.3
51	9/17/1979	2: 0	30.1
52	9/17/1979	3: 0	29.1
53	9/17/1979	4: 0	28.3
54	9/17/1979	5: 0	27.5
55	9/17/1979	6: 0	26.8
56	9/17/1979	7: 0	26.2
57	9/17/1979	8: 0	21.4
58	9/17/1979	9: 0	17.8
59	9/17/1979	10: 0	12.0
60	9/17/1979	11: 0	9.9
61	9/17/1979	12: 0	6.5
62	9/17/1979	13: 0	4.2
63	9/17/1979	14: 0	15.9
64	9/17/1979	15: 0	24.7
65	9/17/1979	16: 0	35.4
66	9/17/1979	17: 0	32.8
67	9/17/1979	18: 0	33.4
68	9/17/1979	19: 0	27.3

69	9/17/1979	20: 0	19.1
70	9/17/1979	21: 0	11.7
71	9/17/1979	22: 0	10.8

Average 20.2
Standard Deviation 12.6
The minimum concentration 2.6 occurred at time step 3 in box 1
The maximum concentration 48.8 occurred at time step 45 in box 1

SADDLE GULCH

TSP concentrations for EIGHT hour averaging time

Time Step Number	Date/Time (mm/dd/yyyy hh:mm)	Concentration (ug/m**3) for box 1
8	9/15/1979 7: 0	7.6
9	9/15/1979 8: 0	8.5
10	9/15/1979 9: 0	9.5
11	9/15/1979 10: 0	10.1
12	9/15/1979 11: 0	10.4
13	9/15/1979 12: 0	10.5
14	9/15/1979 13: 0	9.5
15	9/15/1979 14: 0	13.2
16	9/15/1979 15: 0	17.1
17	9/15/1979 16: 0	21.7
18	9/15/1979 17: 0	25.9
19	9/15/1979 18: 0	30.2
20	9/15/1979 19: 0	29.7
21	9/15/1979 20: 0	28.9
22	9/15/1979 21: 0	29.2
23	9/15/1979 22: 0	25.0
24	9/15/1979 23: 0	20.7
25	9/16/1979 0: 0	16.5
26	9/16/1979 1: 0	12.5
27	9/16/1979 2: 0	8.7
28	9/16/1979 3: 0	9.9
29	9/16/1979 4: 0	11.4
30	9/16/1979 5: 0	12.7
31	9/16/1979 6: 0	13.9
32	9/16/1979 7: 0	14.9
33	9/16/1979 8: 0	14.7
34	9/16/1979 9: 0	14.7
35	9/16/1979 10: 0	13.9
36	9/16/1979 11: 0	12.7
37	9/16/1979 12: 0	11.4
38	9/16/1979 13: 0	9.5
39	9/16/1979 14: 0	12.5
40	9/16/1979 15: 0	14.2
41	9/16/1979 16: 0	17.2
42	9/16/1979 17: 0	19.8
43	9/16/1979 18: 0	27.0
44	9/16/1979 19: 0	32.2
45	9/16/1979 20: 0	35.9
46	9/16/1979 21: 0	40.2
47	9/16/1979 22: 0	39.3
48	9/16/1979 23: 0	39.5
49	9/17/1979 0: 0	39.2
50	9/17/1979 1: 0	38.8
51	9/17/1979 2: 0	34.4
52	9/17/1979 3: 0	32.0
53	9/17/1979 4: 0	31.0
54	9/17/1979 5: 0	29.9

55	9/17/1979	6: 0	28.9
56	9/17/1979	7: 0	28.1
57	9/17/1979	8: 0	25.7
58	9/17/1979	9: 0	23.9
59	9/17/1979	10: 0	21.3
60	9/17/1979	11: 0	18.5
61	9/17/1979	12: 0	15.7
62	9/17/1979	13: 0	12.6
63	9/17/1979	14: 0	14.4
64	9/17/1979	15: 0	15.1
65	9/17/1979	16: 0	17.8
66	9/17/1979	17: 0	20.1
67	9/17/1979	18: 0	23.2
68	9/17/1979	19: 0	24.3
69	9/17/1979	20: 0	24.8
70	9/17/1979	21: 0	26.0
71	9/17/1979	22: 0	22.4

Average 20.8
Standard Deviation 9.3
The minimum concentration 7.6 occurred at time step 8 in box 1
The maximum concentration 40.2 occurred at time step 46 in box 1

SADDLE GULCH

TSP concentrations for 24 hour averaging time

Time Step Number	Date/Time (mm/dd/yyyy hh:mm)		Concentration (ug/m**3) for box 1
24	9/15/1979	23: 0	15.1
25	9/16/1979	0: 0	15.6
26	9/16/1979	1: 0	16.0
27	9/16/1979	2: 0	16.3
28	9/16/1979	3: 0	16.7
29	9/16/1979	4: 0	16.9
30	9/16/1979	5: 0	17.2
31	9/16/1979	6: 0	17.4
32	9/16/1979	7: 0	17.6
33	9/16/1979	8: 0	17.6
34	9/16/1979	9: 0	17.7
35	9/16/1979	10: 0	17.6
36	9/16/1979	11: 0	17.4
37	9/16/1979	12: 0	17.2
38	9/16/1979	13: 0	17.2
39	9/16/1979	14: 0	17.1
40	9/16/1979	15: 0	16.6
41	9/16/1979	16: 0	16.2
42	9/16/1979	17: 0	15.7
43	9/16/1979	18: 0	16.5
44	9/16/1979	19: 0	18.2
45	9/16/1979	20: 0	19.6
46	9/16/1979	21: 0	20.8
47	9/16/1979	22: 0	21.9
48	9/16/1979	23: 0	22.9
49	9/17/1979	0: 0	23.7
50	9/17/1979	1: 0	24.4
51	9/17/1979	2: 0	25.1
52	9/17/1979	3: 0	25.6
53	9/17/1979	4: 0	26.1
54	9/17/1979	5: 0	26.5
55	9/17/1979	6: 0	26.9
56	9/17/1979	7: 0	27.2

57	9/17/1979	8: 0	27.4
58	9/17/1979	9: 0	27.5
59	9/17/1979	10: 0	27.5
60	9/17/1979	11: 0	27.6
61	9/17/1979	12: 0	27.6
62	9/17/1979	13: 0	27.6
63	9/17/1979	14: 0	27.6
64	9/17/1979	15: 0	27.6
65	9/17/1979	16: 0	27.6
66	9/17/1979	17: 0	27.6
67	9/17/1979	18: 0	26.3
68	9/17/1979	19: 0	25.0
69	9/17/1979	20: 0	23.8
70	9/17/1979	21: 0	22.8
71	9/17/1979	22: 0	21.9

Average		21.7				
Standard Deviation		4.7				
The minimum concentration	15.1	occurred at time step	24	in box	1	
The maximum concentration	27.6	occurred at time step	61	in box	1	